



한국응용곤충학회  
KOREAN SOCIETY OF APPLIED ENTOMOLOGY



한국응용곤충학회

# 50주년 기념 국제 심포지엄

INTERNATIONAL SYMPOSIUM ON CELEBRATION  
OF THE 50TH ANNIVERSARY OF THE  
KOREAN SOCIETY OF APPLIED ENTOMOLOGY

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Organized by : Korean Society of Applied Entomology | Korea National Academy of Agricultural Science, RDA

Sponsored by : National Research Foundation of Korea | The Korean Federation of Science and Technology Societies | Korea Forest Research Institute  
Korea Pest Control Association | Korea Crop Protection Association

※ 표지 사진은 경상대학교 안수정 회원께서 제공하여 주셨습니다.





# 개 회 사

한국응용곤충학회 회원여러분, 그리고 내외 귀빈 여러분!  
안녕하십니까?

만물이 소생하는 가정의 달 5월에 청정하고 수려하기로 소문난 이곳 홍천에서 여러 선배님, 동료들 및 후배님들을 건강한 모습으로 다시 뵙게 되어 대단히 반갑습니다.

특히 우리학회의 50주년 기념행사를 축하해주시고 특강을 해주시기 위해 참석해주신 일본 Akira Kawai 회장님, 중국 Huang, Da-wei 회장님, 대만 Kuang Hui Lu 회장님, 말레이시아 Mohamad Roff Bin Mohd Noor 회장님 그리고 미국에서 오신 Miller 교수님과 David Gammel 선생님께 진심으로 감사를 드립니다.

여러분들도 잘 아시는 바와 같이 올해는 우리학회가 설립된 지 50주년이 되는 해입니다. 우리 한국응용곤충학회는 1962년 창립 이래, 작물보호분야에서 농작물 해충과 관련되는 모든 학문의 발전을 선도적으로 주도해 왔으며, 이제는 위생해충과 산업곤충분야에서도 중추적인 역할을 수행하며 양적으로나 질적으로 괄목할 만한 성장을 해 왔습니다.

그동안 응용곤충학의 학술활동에 꾸준히 참여해 오신 모든 분들께 이 자리를 빌어 감사의 인사를 드립니다.

존경하는 회원 여러분!

최근의 기후변화에 따른 영향은 한반도를 포함한 지구촌 곳곳에서 신종플루, 조류독감, 돌발 해충 등의 다양한 형태로 나타나고 있으며, 또한 지구온난화가 지속됨에 따라 자연재해가 빈번하게 발생하고, 자연생태계의 교란으로 인해 새롭게 발생하는 질병 등은 재앙이라는 표현이 적절할 정도로 우리 인류에게 큰 위협이 되고 있는 실정입니다.

# INTERNATIONAL SYMPOSIUM ON CELEBRATION OF THE 50TH ANNIVERSARY OF THE KOREAN SOCIETY OF APPLIED ENTOMOLOGY



특히 곤충 생태계의 변화는 농업해충과 위생·산림·가축해충의 행동들이 새로운 형태로 상호 연계되고 있으며, 따라서 우리 응용곤충학 분야에서는 상호 연관된 생태계의 체계 안에서 이들의 방제기술과 방법을 새롭게 규명해야 할 필요성이 시급히 요구되는 실정입니다.

과거의 역사를 살펴 볼 때, 시대적 요구에 따라 학문의 융성과 쇠퇴가 좌우되어 왔습니다. 이에 따라 우리 학회에서는 한국응용곤충학회 창립 50주년을 기념하여 국내외 저명한 학자들과 아·태 지역 국가들의 응용곤충학분야 학회장님들이 한 자리에 모여 각자 자기 나라의 응용곤충학분야 연구현황과 발전방안에 대한 의견을 교환하고, 역내 국가들 간에 응용곤충학 분야의 발전과 상생의 협력체계를 구축할 수 있는 토론의 장을 제공함으로써 시대적 요구에 부응하는 학회로 성장시키기 위한 계기를 마련하게 되었습니다.

회원 여러분!

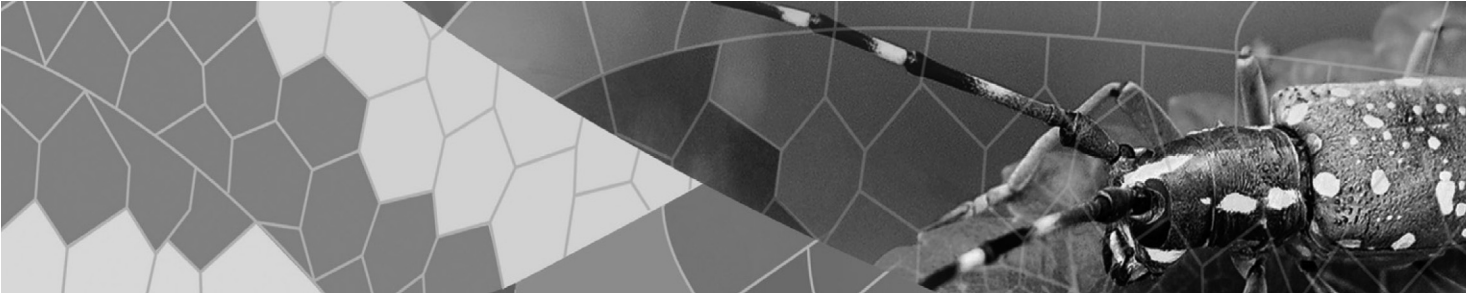
50년이라는 기간은 아이가 태어나 청장년기를 거쳐 인생의 완성기에 접어드는 시간입니다. 우리 학회도 그간 연간 등록회원 600명이라는 장족의 발전을 거듭하고 있지만, 아직도 세계의 우수 학회들과 비교할 때 무한한 성장 가능성을 내포하고 있는 단계입니다.

이번 심포지엄을 통해서 그동안 우리나라 응용곤충학 연구 50년의 발자취를 되돌아보고 앞으로 우리나라 응용곤충학의 발전방안을 새로운 시각으로 모색해 볼 수 있는 계기가 될 것이라 확신하며, 또한 향후 우리학회가 세계 응용곤충학분야의 연구발전을 위해 더 많은 역할을 하는 계기가 되기를 진심으로 기원합니다.

끝으로 이 자리에 참석하신 모든 분들의 가정에 건강과 행복이 늘 함께하기를 다시 한 번 기원 드리며, 한국응용곤충학회 50주년 행사 시작을 선언합니다.

고맙습니다.

2011년 5월 12일  
사단법인 한국응용곤충학회  
제 28대 회장 안 용 준



# Opening Remarks

Good afternoon, ladies and gentlemen!

A warm welcome to our visitors, invited speakers and members of the Korean Society of Applied Entomology. I am very happy that you have joined us again today to celebrate our 50th Annual meeting here in the beautiful place of Hongcheon.

I highly appreciate the presence of Dr. Akira Kawai from Japan, Dr. Huang Da Wei from China, Dr. Kuang Hui Lu from Taiwan, Dr. Mohamad Roff Bin Mohd Noor from Malaysia and Dr. Miller and Mr. David Gammel from USA who are all providing the lectures.

This year, we celebrate our 50th anniversary since KSAE was established in 1962. Our society has been playing an important role for crop protection, especially on pest management and the advancement of entomology. We are also contributing quantitatively and qualitatively to the development of medical entomology and industrial entomology. Thank you very much to all KSAE members for your efforts in making our scientific society an excellent society.

Recently, climate change and diverse unpredictable weather are occurring more often around the world. Climate change causes natural disasters and ecosystem disturbance and as a result, become a big threat to humankind, for example, swine influenza and outbreak of noxious pest based on potential pests. The changes in our insect ecosystem is linked with all entomology areas including agriculture, medicine, forestry, livestock and so on. We must urgently answer the method and technology for pest management within these connected ecosystems.



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Throughout history, the rise and fall of science depends on the demand of times. To celebrate 50th anniversary of the society and to meet the requirements of this age, we invited distinguished entomologists from Six countries - Japan, China, Taiwan, Malaysia, USA and Australia. This is a great event to exchange information on the current status of entomology, including pest management, and to discuss future cooperation. I hope that a worldwide development of entomology could be achieved based on this international meeting.

I think that 50 years is a long period, like a baby growing into adulthood. Like this, our society have had important periods in the last 50 years. We had many outstanding scientific achievements and the membership of our society increased to 600 members. Now, it is time for a new leap forward, to be stronger, and to be a more competitive society in the world.

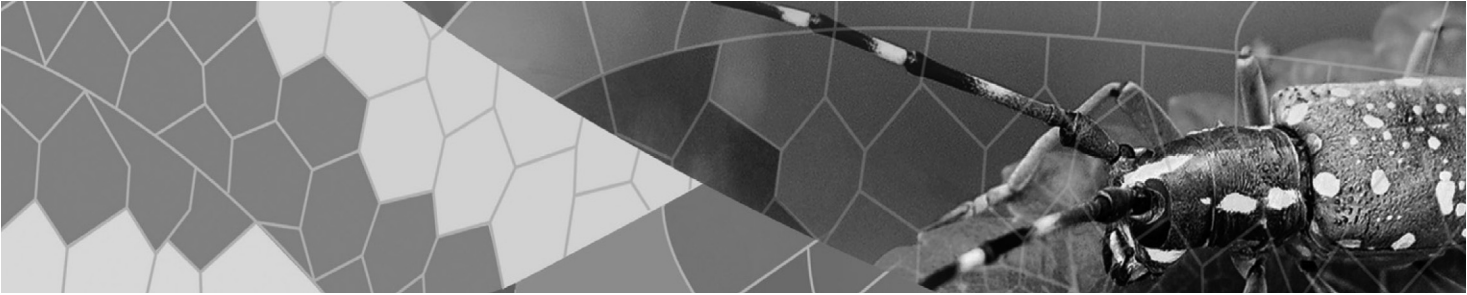
I hope that, as we look back into our last 50 years, we have developed and will have the opportunity to find future direction for the development of applied entomology in Korea through this symposium.

I wish you all good health and happiness.  
Thank you.

May 12, 2011

**YONG-JOON AHN**

President, Korean Society of Applied Entomology



# 환영사

한국응용곤충학회 회원여러분, 그리고 내외 귀빈 여러분, 안녕하십니까? 만물이 다시 소생하는 봄날, 청정한 이곳 강원도 홍천에서 응용곤충학을 연구하는 여러분들을 만나뵙게 되어 대단히 반갑습니다.

특히 오늘은 한국응용곤충학회 창립 50주년을 맞이하여 본 학회와 농촌진흥청이 공동으로 주최하는 한국응용곤충연구 50주년 기념 국제심포지엄에 참석하신 국내외 귀빈 여러분들에게 깊은 감사의 말씀을 드리며, 이처럼 뜻 깊은 자리에서 제가 환영사를 하게 된 것을 매우 영광스럽게 생각합니다.

한국응용곤충학회는 1962년에 전신인 한국식물보호학회로 창립된 이래, 응용곤충학과 선충학, 응애학, 농약학 등에 관련되는 제 분야의 발전을 위하여 수 많은 기여를 해왔으며, 이제는 명실공히 우리나라의 대표적인 한 학회가 되었습니다.

농업생산성을 높이기 위해 작물학, 육종학, 기후학, 토양학 등의 많은 학문 분야가 그 역할을 묵묵히 수행해 왔지만, 이러한 분야들 못지않게 작물의 안정적 생산을 위하여 작물보호 분야의 연구가 매우 중요한 것은 주지의 사실이며, 그 동안 열악한 환경을 극복하고, 한국응용곤충학회가 작물보호 분야에서 그 역할을 충실히 수행해 온 것에 대해 농촌진흥청 국립농업과학원을 대표하여 깊은 감사를 드립니다.

한국응용곤충학회 회원여러분! 최근의 기후변화와 관련하여 작물에 돌발적으로 발생하는 해충으로 인해 농가의 생산성에 큰 위협이 되고 있습니다. 그러나 저는 본 학회의 회원여러분들이 현장연구를 통해 이러한 돌발해충에 대한 문제들을 잘 해결할 수 있을 것으로 굳게 믿고 있으며, 저 또한 본 학회의 발전을 위해 힘이 닿는 데 까지 도와드릴 것을 약속드립니다.

아무쪼록 한국응용곤충학회가 창립 50주년 기념 국제심포지엄을 계기로 세계 응용곤충학 연구의 선두주자로 발돋움할 수 있는 계기가 되기를 중심으로 바라며, 이 자리에 참석하신 모든 분들의 가정에 건강과 행복이 늘 함께 하길 기원합니다. 감사합니다.

2011년 5월 12일  
국립농업과학원장 정 광 용



# Welcome Remarks

Good afternoon, ladies and gentlemen!

On behalf of the Korean Society of Applied Entomology, I warmly welcome all of you to the Korean Society of Applied Entomology here in Hongcheon, Gangwon province on this wonderful day of spring.

It is my pleasure and honor to give the welcome remarks in this very meaningful meeting. Especially, I would like to express my heartfelt thanks to all the participants, those who came from overseas and from Korea, for attending this International Symposium to Celebrate the 50<sup>th</sup> Anniversary of the Korean Society of Applied Entomology. I like to thank the organizers - the RDA (Rural Development Administration) and the Korean Society of Applied Entomology (KSAE).

Since the Korean Society of Applied Entomology (KSAE), formerly known as Korean Society of Plant Protection, was established in 1962, it has greatly contributed to the development of applied entomology, nematology, acarology, and pesticide science and a representative crop protection society of Korea, indeed as well as in name.

As President of the National Academy of Agricultural Science, let me extend my gratitude to the members of KSAE who have faithfully performed their studies on crop protection.

Crop protection research plays a crucial role in enhancing the quality and safety of agricultural products with other fields of study such as crop science, climatology, and soil science. Recently, several insect pests occurred accidentally, brought about by climate change, and threatened agricultural production in Korea. However, I am confident that this agricultural crisis will be solved through research by our KSAE members. On my part, I promise to support the research and development activities of KSAE.

Finally, I sincerely wish that KSAE will become the leader, if not one of the leaders, of applied entomology in the world with this 50<sup>th</sup> Anniversary International Symposium of KSAE.

Again, a warm welcome to you all. I wish you a successful symposium. Enjoy the symposium and enjoy Korea!

Thank you.

May 12, 2011

**Kwang-Yong, Jung**

President, National Academy of Agricultural Science (NAAS)





# Program

**12 May 2011**

	Grand Ballroom
12:00~13:00	Registration
13:00~14:00	Opening ceremony Opening address (President of Korean Society of Applied Entomology) Welcome address (President of NAAS) Congratulatory address (President of Korea Pest Control Association) Congratulatory address (Governor of Hongcheon-Gun)
14:00~14:35	<b>Section I : Current status and future of applied entomology in Asia</b> <b>50 years history of Korean Society of Applied Entomology</b> (Dr. Kyung Saeng Boo, Former president of KSAE)
14:35~15:10	<b>Current status and future of applied entomology in Japan</b> (Dr. Akira Kawai, President of the Japanese Society of Applied Entomology)
15:10~15:45	<b>Current status and future of applied entomology in China</b> (Dr. Da-wei Huang, President of the Entomological Society of China)
15:45~16:00	Coffee / Tea Break
16:00~16:35	<b>Current status and future of applied entomology in Taiwan</b> (Dr. Kuang Hui Lu, President of the Taiwan Society of Applied Entomology)
16:35~17:10	<b>Current status and future of applied entomology in Malaysia</b> (Dr. Mohamad Roff Bin Mohd Noor, President of the Malaysia Plant Protection)
17:10~17:45	<b>Current status and future of applied entomology in USA</b> (Dr. Thomas A. Miller, Delegate of the Entomological Society of America)
17:45~18:00	<b>Opportunities for International Collaboration with the Entomological Society of America</b> (Dr. David Gammel, Executive Director of Entomological Society of America)
18:00~18:15	Discussion
19:00~21:00	Welcome Dinner

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**13 May 2011**

Grand Ballroom	
09:00~09:30	Plenary session
09:35~10:10	<b>Current status and future of applied entomology research in Australia</b> (Dr. James Ridsdill-Smith, Delegate of the Australian Society of Entomology)
10:30~11:00	<b>Session II : New technology in entomology research</b> <b>New technology for modeling and monitoring of insect pests</b> (Dr. Joon-Ho Lee)
11:00~11:30	<b>Application of molecular technology in insect pest management</b> (Dr. Si Hyeock Lee)
11:30~12:00	<b>Application of bar-code in entomology</b> (Dr. Ho Yeon Han)
12:00~13:30	Lunch
13:30~14:00	<b>Development of Bio-resources from insects</b> (Dr. Ho Yong Park)
14:00~14:30	<b>Disruption of insect physiological processes and novel control strategies.</b> (Dr. Yong Gyun Kim)
14:30~15:00	<b>Session III : Current status and future of insect pest management in Korea</b> <b>Insect pest management in rice</b> (Dr. Ki Yeol Lee)
15:00~15:30	<b>Insect pest management in fruit tree orchards</b> (Dr. Myoung Rae Cho)
15:30~15:45	Coffee/Tea Break
15:45~16:15	<b>Insect pest management in greenhouse crops</b> (Dr. Man Young Choi)
16:15~16:45	<b>Forest insect pest management</b> (Dr. Yeong Jin Chung)
16:45~17:15	<b>Management of medical insects</b> (Dr. E-Hyun Shin)
17:15~17:45	<b>Insect pest management and Quarantine</b> (Dr. Ki Jeong Hong)
18:00~18:40	Discussion

**14 May 2011**

Crystal / Ruby / Coral / Jade	
09:00~12:00	Oral presentations

**13~14 May 2011**

Grand Ballroom	
09:00~12:00	Poster presentations

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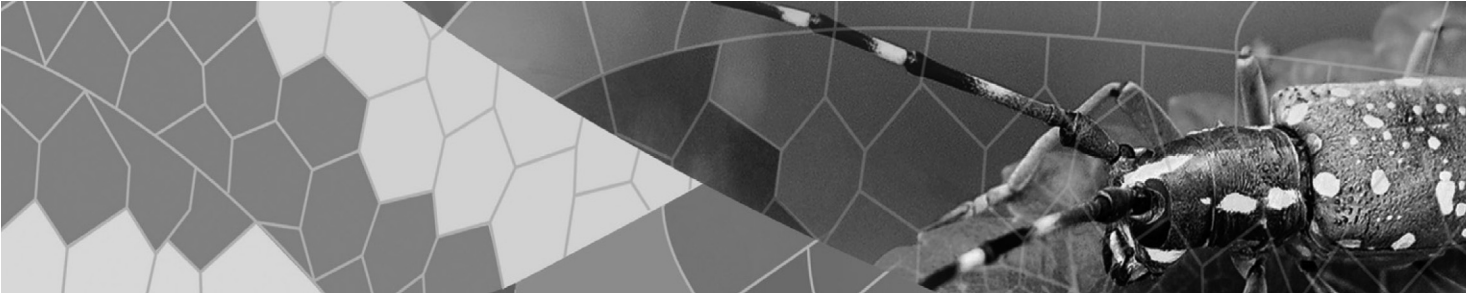
**5,13 (Fri) Grand Ballroom**

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●●● 구두 발표

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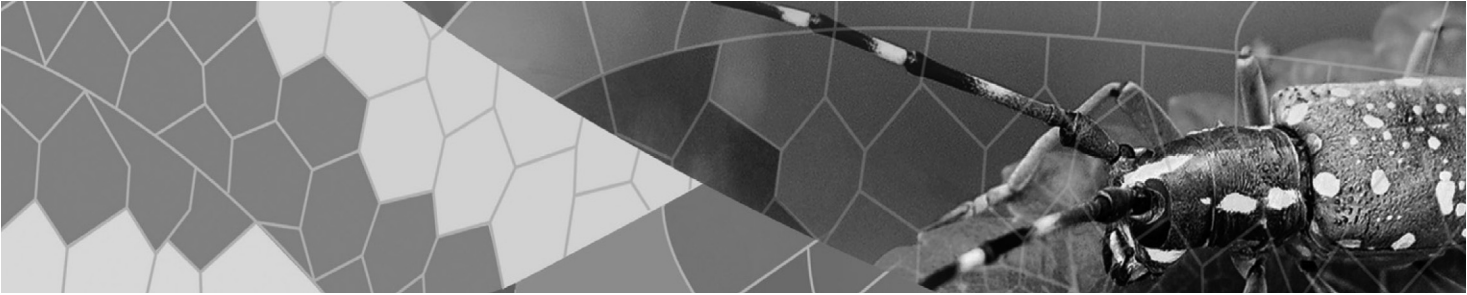
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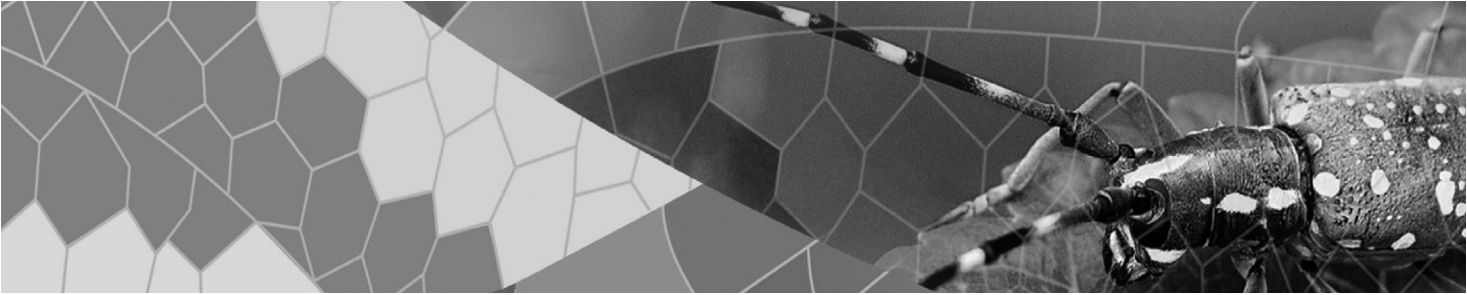
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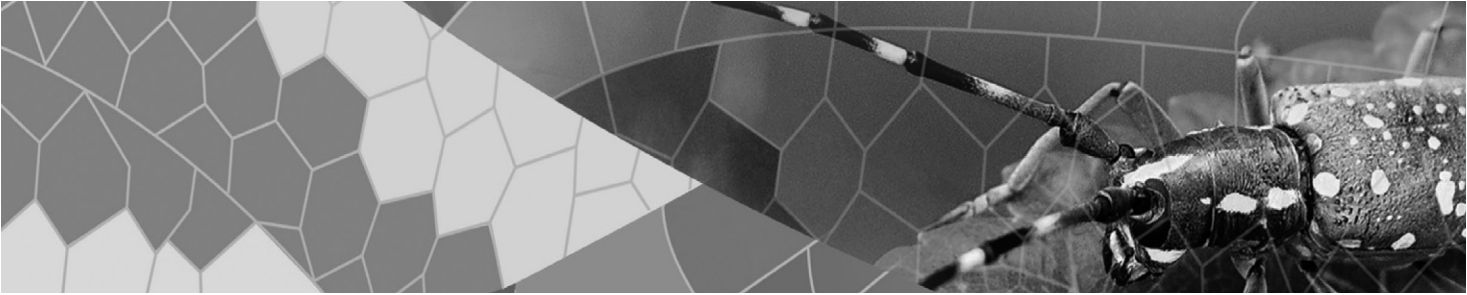


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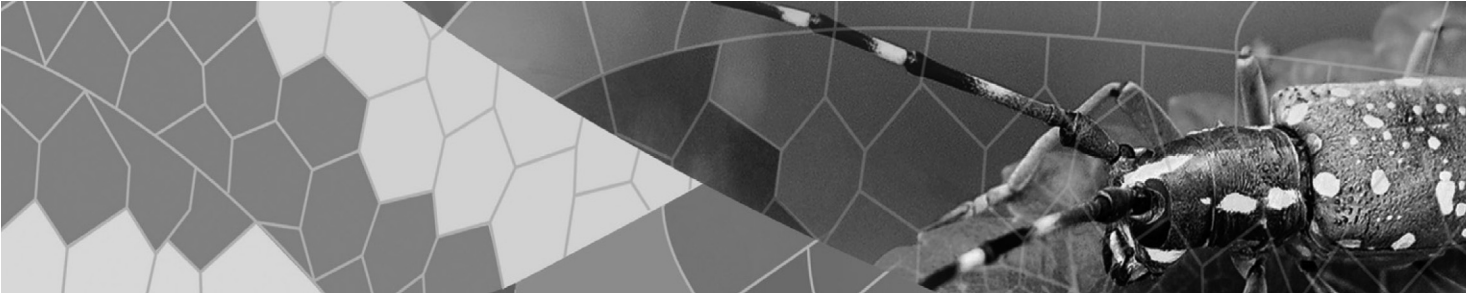
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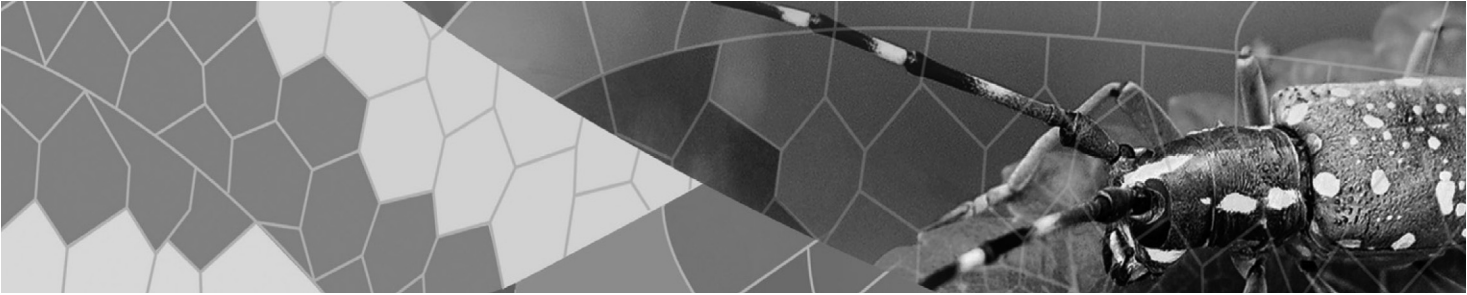


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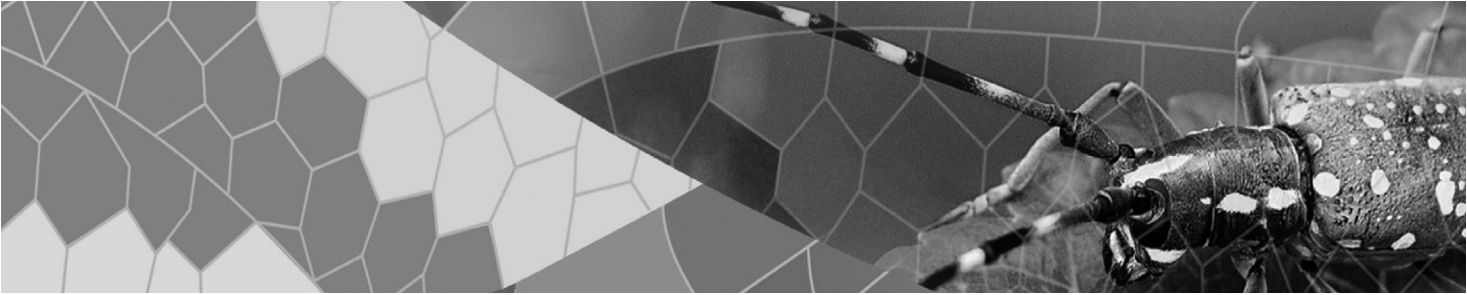


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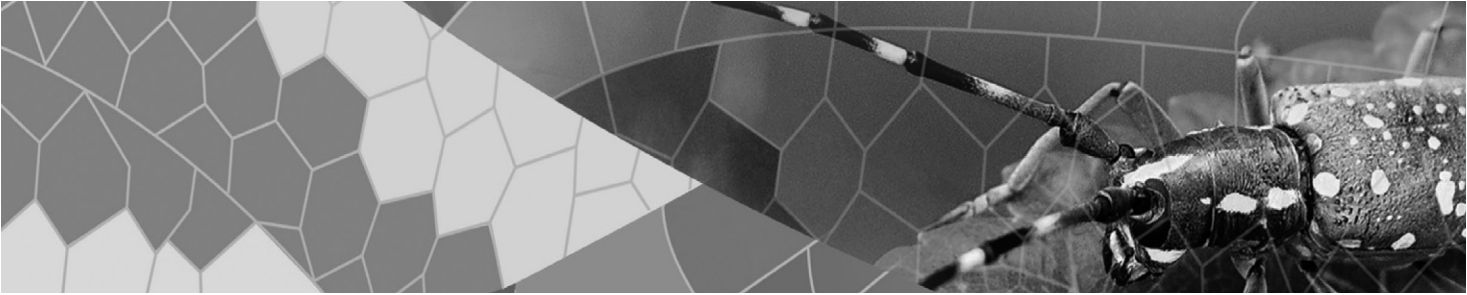
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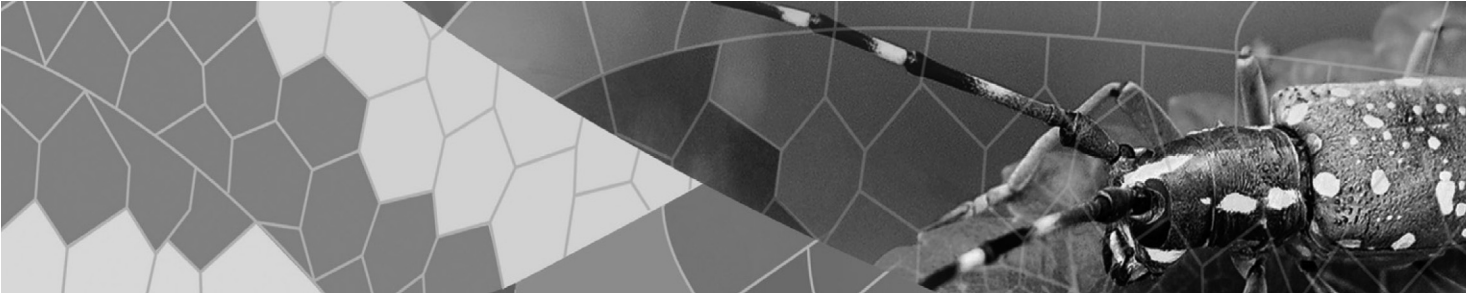
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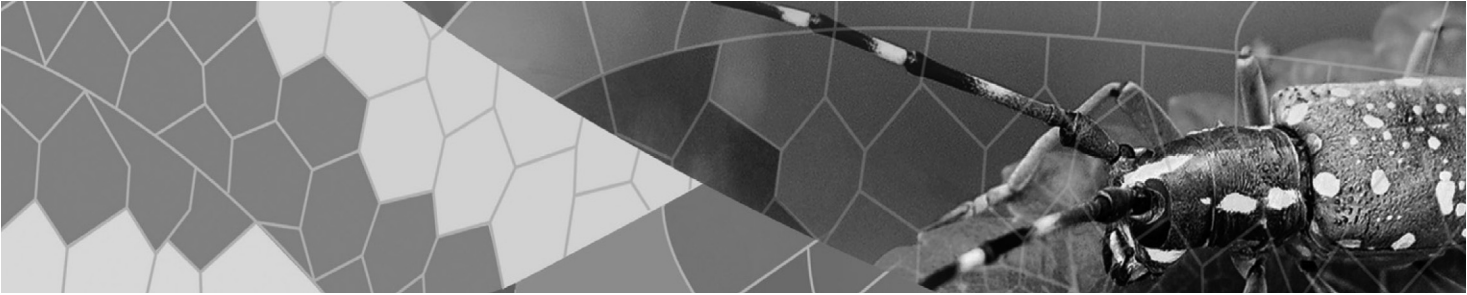
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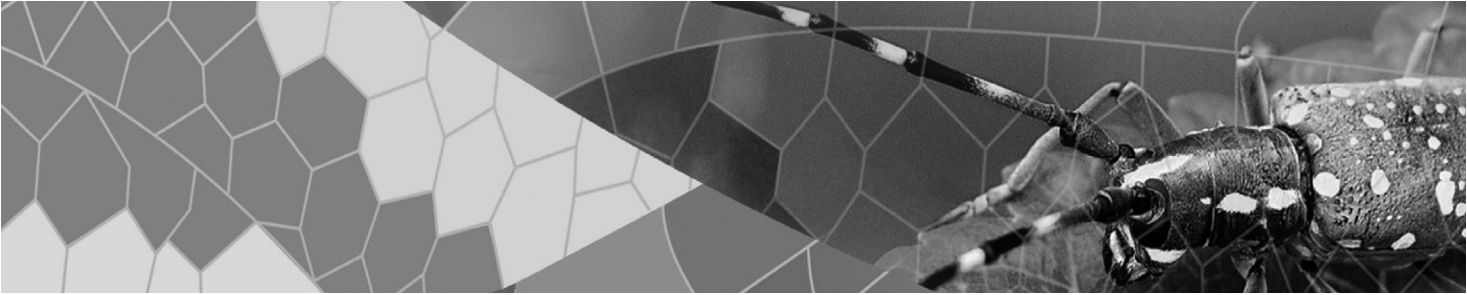


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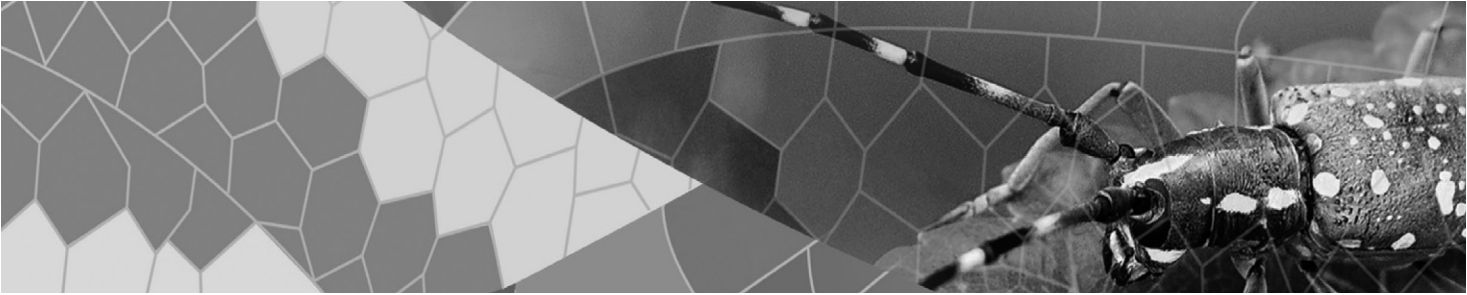
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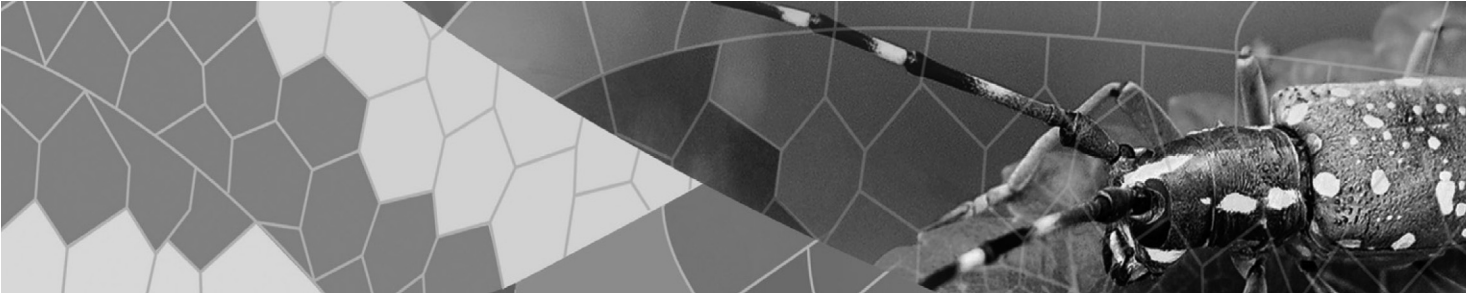
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# 초청연사

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## **The history of the Korean society of applied entomology for its first 50 years**

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The Korean Society of Applied Entomology (KSAE) celebrates its First 50 years history this year, 2011. It began in the year 1962, as the Korean Society of Plant Protection (KSPP) (Table 1) to discuss all aspects of plant protection including entomology and plant pathology. At that period it was one of the earliest scientific societies in Korea.

Before liberation from the Japanese colonial rule there were a few societies for Japanese scientists only in the Korean Peninsula. It seemed that there was a single exception, in medical field, formed by and operated for Korean ethnics. Right after the liberation, Korean scientists rushed to form new scientific societies in the fields of mechanical engineering, architecture, textile, internal medicine, biology, etc. in 1945, mathematics, chemistry, metallurgy, etc. in 1946, and so on. But agricultural scientists had to wait for more time before setting up their own society, Korean Agricultural Society(韓國農學會), comprising all agricultural subfields, in 1954. They had annual meetings and published their own journal every year until 1962. Then those working in the plant protection field established their own KSPP, right after their section meeting in 1962 (Table 1). At that time the total number of participants for KSPP were only around 50.

KSPP scientists were interested in plant pathology, agricultural chemicals, weed science, or bioclimate, besides entomology. They had annual meetings once or twice a year until 1987 (Table 2) and published their own journal, Korean Journal of Plant Protection (KJPP), once a year at the earlier years but soon gradually increasing the frequency to four times a year later. Articles on entomology and plant pathology occupied about 40% each (Table 3), but the number of oral or posters were a little bit higher on plant pathology than entomology (Table 2), with the rest on nematology, agricultural chemicals, or soil

microarthropods. There also had a number of symposia and special lectures (Table 3). The presidency lasted for two years and most of president served only one term, except for the first two (Table 1). The current president should be 28<sup>th</sup>.

In the year 1988, KSPP had to be transformed into the applied entomology society, KSAE, because most of plant pathologists participating left the society to set up their own one, Korean Society of Plant Pathology in 1984. Since that time the Society concentrates on entomology, basic and applied, with some notes on nematology, acarology, soil microarthropods, agricultural chemicals, etc. The Society has been hosting annual meetings at least twice a year with special lectures and symposia, from time to time, on various topics (Table 3). It also hosted international symposia including binational scientific meetings twice with two different Japanese (applied entomology in 2003 and acarology in 2009) societies and the Asia-Pacific Congress of Entomology in 2005. The regular society meeting of this year turns out to be the 43<sup>rd</sup> and this autumn non-regular meeting would be the 42<sup>nd</sup>. It has been publishing two different scientific journals, Korean Journal of Applied Entomology (KJAE) since 1988 and the Journal of Asia-Pacific Entomology (JAPE) since 1998 (Table 3). Both journals are published 4 times a year, with articles written in Korean or English in the first, but those in English only in the latter with cooperation from the Taiwan Entomological Society and the Malaysian Plant Protection Society since 2008. It is now enlisted as one of those SCI extended.

The highest number of topics discussed at their annual meetings was on ecology, behavior, and host resistance. But at the annual meetings jointly with the Korean Society of Entomology, interested more on basic aspects, physiology and molecular biology fields took over the top position (Table 2).

Among those societies related to entomology and plant protection, plant pathology, pesticide, and applied entomology societies are almost similar in membership, but entomology and plant pathology societies are publishing more number of articles than any others (Table 4).

The Society is running beautifully, but there are a few points to be made for further improvement. First, the articles or posters should be correctly categorized on the journals or proceedings. It may be a good idea to ask members to give their own version of correct category for their submissions, either oral or poster or written publication. The category should be classified detailed as much as possible (one kind of example would be systematics, morphology, evolution, ecology, behavior, host preference or resistance, physiology, anatomy, chemical ecology, molecular biology, pathology, chemical control, insecticides, insecticide resistance, biocontrol, natural enemies, agricultural pest, forest pest, medical pest, etc.) and such scheme should be given to members beforehand. The members should give one or two, first and second, choices when submitting, if they want. Then the categories might be combined or grouped during editing for optimal arrangement for journals or proceedings. Secondly the journals should carry complete content of the particular year and author index at the last issue of that year.

I would also like to have other information, such as awards and awardees in handy way. I could not find any document for listing awards. Such information or article categorization may be assigned to one of the vice presidents. I would rather strongly recommend that the society should give more time and energy on archive management to keep better and more correct history records.

< 첨부 >

표 1. Officers of the Korean Society of Plant protection and the Korean Society of Applied Entomology (한국식물보호학회와 한국응용곤충학회의 임원진)

Officers of the Korean Society of Plant Protection						
Term	Period	President	Vice Presidents	Secretary-Treasurer	Editor-in-Chief	Editing Secretary
1st	1962 ~ 1964	백운하		최승윤		나용준
2nd	1964 ~ 1966	백운하	박종성, 이성환	조용섭		최승윤
3rd	1966 ~ 1968	박종성	이성환, 현재선	강인목		박중수, 최승윤
4th	1968 ~ 1969	박종성	이성환, 현재선	나용준		최승윤
5th	1969 ~ 1970	이성환	김문호, 정후섭	우건석	현재선	최승윤
6th	1970 ~ 1971	정후섭	김문호	우건석	현재선	최승윤
7th	1971 ~ 1973	현재선	배대한, 정봉조	우건석	배대한	조용섭
10th	1977 ~ 1979	최승윤	윤태규, 조용섭	우건석	조용섭	김상석
14th	1985 ~ 1987	조용섭	우건석, 이경휘	부경생	우건석	
Officers of the Korean Society of Applied Entomology						
15th	1988 ~ 1990	우건석	김창효, 최귀문	부경생	최귀문	
20th	1995 ~ 1996	이영인	부경생, 배태웅, 김규진, 이병현	추호렬	부경생	이준호, 권용정
25th	2004 ~ 2006	송유한	김태홍, 김근영, 류문일, 심재영, 엄기백, 이상몽	최동로, 배양섭	류문일	김길하, 김용균/이시현, 윤영남
26th	2006 ~ 2008	김태홍	류문일, 박종대, 심재영, 안용준, 이상몽, 최동로	배양섭	이준호	윤영남, 이승환, 윤영남
27th	2008 ~ 2010	류문일	안용준, 박정규, 박종대, 신성철, 전병철, 최동로	이상계	이준호	윤영남
28th, current	2010 ~ 2012	안용준	이준호, 고현관, 박정규, 박종대, 박호용, 신성철, 유용만, 전병철, 최동로, 최영철	이상계	이준호	윤영남

표 2. Number of Oral Papers or Posters discussed at the Annual Meetings of the Korean Society of Plant Protection and of Applied Entomology (식물보호와 응용곤충 학회의 학술발표회에서 보고된 논문 수 비교)

Number of Oral Papers or Posters at Annual Meetings of the Korean Society of Plant Protection									
Year presented	Total Number	Entomology		Plant Pathology	Others	Symp. or Special Lectures			
발표 연도	총 논문수	곤충학		식물병리학	기타	심포지엄, 특강			
1962 ~ 1987	850 (%)	327 (38.5)		427 (50.2)	96 (11.3)	73			
Korean Society of Applied Entomology									
Year presented (연도)	Total Number	Systematics <sup>1</sup>	Ecology <sup>2</sup>	Physiol. <sup>3</sup>	Control <sup>4</sup>	Bio-control <sup>5</sup>	Others <sup>6</sup>	Symp. or Special Lectures	*8
1988 ~ 2010	총 논문수	분류, 형태	생태, 행동	생리, 병리, 화학생태	방제, 저항성	천적, 생방	기타	심포지엄, 특강	
소계 (독립)	2,515 (%)	391 (15.6)	740 (29.4)	513 (20.4)	368 (14.6)	346 (13.8)	157 (6.2)	179	179
소계 (joint)	1,554 (%)	301 (19.4)	385 (24.8)	472 (30.4)	173 (11.1)	176 (11.3)	47 (3.0)	104	104
총계	4,069 (%)	692 (17.0)	1,125 (27.7)	985 (24.2)	541 (13.3)	522 (12.8)	204 (5.0)		283

\*1: Systematics, Morphology, Evolution; \*2: Ecology, Behaviour, Host Resistance; \*3: Physiology, Pathology, Ultrastructure, Molecular Biology, Chemical Ecology; \*4: Control, Chemical Control, Insecticides; \*5: Biocontrol, Natural Enemies, Biorational Control, Pheromonal Control, Resistant Host; \*6: Nematodes, Spiders, Microarthropods, Others; \*7: Number of Papers given at a Symposium or Special Lectures; \*8: Joint Meeting with Korean Society of Entomology for Oral Presentation or Posters; # Joint meeting with another society

표 3. Number of articles published on the Korean Journal of Plant Protection, the Korean Journal of Applied Entomology, and the Asia-Pacific Journal of Entomology (응용곤충학자들이 관여한 세가지 학술지에 발표된 논문들의 속성 비교)

Number of Articles on the Korean Journal of Plant Protection / 한국식물보호학회지										
J. Vol. No.	Year Issued	Total Number	Entomology		Plant Pathology		Others	Other than Sci. Articles	Symp., special Lectures <sup>7</sup>	Total Pages
권	연도	총 논문수	곤충학		식물병리학		기타	논문 외 기사	심포지엄, 특강	총 쪽수
1st ~ 26th	1962~1987	642 (%)	279 (43.5)		256 (39.9)		107 (16.6)	95	73	4,579
Korean Journal of Applied Entomology / 한국응용곤충학회지										
J. Vol. No.	Year Issued	Total Number	Systematics <sup>1</sup>	Ecology <sup>2</sup>	Physiol. <sup>3</sup>	Control <sup>4</sup>	Bio~control <sup>5</sup>	Others <sup>6</sup>	Symp., special Lectures <sup>7</sup>	Total Pages
권	연도	총 논문수	분류, 형태	생태, 행동	생리, 병리, 화학생태	방제, 저항성	천적, 생방	기타	심포지엄, 특강	총 쪽수
27th~49th	1988~2010	1073	206 (18.7)	346 (32.3)	145 (13.5)	160 (14.9)	160 (14.9)	61 (5.7)	181	8,823
Journal of Asia-Pacific Entomology / 아시아-태평양곤충학회지										
J. Vol. No.	Year Issued	Total Number	Systematics <sup>1</sup>	Ecology <sup>2</sup>	Physiol. <sup>3</sup>	Control <sup>4</sup>	Bio~control <sup>5</sup>	Others <sup>6</sup>	Symp., special Lectures <sup>7</sup>	Total Pages
권	연도	총 논문수	분류, 형태	생태, 행동	생리, 병리, 화학생태	방제, 저항성	천적, 생방	기타	심포지엄, 특강	총 쪽수
1st ~ 13th	1998~2010	Total (%)	140 (25.7)	110 (20.2)	108 (19.8)	82 (15.1)	91 (16.7)	14 (2.5)		3,729

표 4. Current Status of Plant Protection-Related Societies (식물보호와 관련된 학회들과 곤충학회의 회원수, 학회지, 논문수 비교)

Current Status of Related Societies									
Name of Societies	Year	No. Members	Publication of Society Journals						
			Korean Language Journals			English Language Journals			Total No. Articles
			Name	Publication		Name	Publication		
				per Year	No. Articles		per Year	No. Articles	
한국응용곤충학회 Korean Soc. Appl. Entomol.	2007	405	한국응용곤충학회지	3	58	J. Asia-Pacific Entomol.	4	58	116
	2008	518		4	67		4	44	111
	2009	608		4	54		4	54	108
한국식물병리학회 Korean Soc. Plant Pathol.	2007	413	식물병연구	3	43	The Plant Pathol. J.	4	55	98
	2008	427		3	46		4	64	110
	2009	827		3	43		4	68	111
한국농약과학회 Korean Soc. Pesticide Sci.	2007	643	농약과학회지	4	43				43
	2008	645		4	59				59
	2009	598		4	44				44
한국잡초학회 Korean Soc. Weed Sci.	2007	360	한국잡초학회지	4	43	Weed Biology and Management	4	10	53
	2008	244		4	51		4	40	91
	2009	254		4	45		4	42	87
한국곤충학회 Entomol. Soc. Korea	2007	108				Entomological Research	4	48	48
	2008	423					4	48	48
	2009	504					4	61	61

**Key words:** Korean Society of Applied Entomology, KSAE fifty years history, Korean Society of Plant Protection, Korean Journal of Plant Protection, Korean Journal of Applied Entomology, Journal of Asia-Pacific Entomology. Journal publication, proceedings of annual meetings

## **Current status and future of applied entomology in Japan**

**Akira Kawai**

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### **Present status of pest control in Japan**

In Japan, farmers tend to rely on chemicals to control pests, and they spray many times. Total pesticide use in Japan is 15.5kg /ha in active ingredients, which is the maximum in the world. It decreases but the speed is very slow. Though researches on integrated pest management (IPM) system were densely studied since 1970, the systems were introduced a little by farmers.

### **Policy of Japan for sustainable agriculture**

In the Promotion Principles of the Environmental Friendly Agriculture announced in 1994, Ministry of Agriculture, Forestry and Fisheries (MAFF) showed the importance of environmental friendly agriculture and the reduction of agricultural chemicals. MAFF made the Law for Promoting the Introduction of Sustainable Agricultural Production Practices in 1999. By the law, each prefectural government has to establish guidelines for the introduction of sustainable agricultural production practices in its prefecture, and government has to assist the farmers with sustainable agriculture. Further, in the Principles of the Environmental Policy in Agriculture, Forestry and Fisheries announced in 2004, MAFF showed the encouraging transition to an environmentally conscious agriculture, and integrated pest management system should be promoted in the policy.

The research project ‘Development of new IPM system for sustainable agriculture’ conducted during 1999-2003 by MAFF. In the project, practical IPM systems of 10 crops (rice, potato, soybean, tomato, eggplant, melon, cabbage, mandarin, Japanese pear, tea) were shown, and many new techniques which will be used in IPM system in the future were developed. On the basis of these IPM systems, each prefectural government is making guidelines for the introduction of IPM practices in its prefecture.



### **Establishment of the Union of Japanese Societies for Insect Sciences**

In Japan, there are several societies on entomological science; the Japanese Society of Applied Entomology and Zoology (mainly agricultural entomology), the Entomological Society of Japan (general entomology), the Japanese Society of Sericultural Science (sericultural science and insect biotechnology), the Japan Society of Medical Entomology and Zoology (medical entomology), and so on. Moreover, Society for Bioscience, Biotechnology, and Agrochemistry, the Zoological Society of Japan and Pesticide Science Society of Japan deals with entomological researches on respective area. In order to solve various problems on entomological sciences totally, the Union of Japanese Societies for Insect Sciences was established with 14 insect related societies in July, 2010. Besides the above mentioned 7 societies, Acarological Society of Japan, Arachnological Society of Japan, the Society for the Research of House and Household Insect Pests, Japan, Japanese Society of Environmental Entomology and Zoology, the Japanese Society for Comparative Physiology and Biochemistry, the Japanese Society for Wild Silkmoths and the Lepidopterological Society of Japan participate the union.

### **Recent topics on applied entomology in Japan**

Various aspects of research on applied entomology are studied in Japan. Recent topics are as follows:

#### 1. IPM in plastic house using indigenous natural enemies

Formerly, natural enemies used in IPM in plastic house are mainly exotic species. Recently, several indigenous natural enemies are used in IPM in plastic house. Both reproduction in laboratory and technique for conservation in the field are well employed.

#### 2. IPM of tomato yellow leaf curl virus (TYLCV) transmitted by *Bemisia tabaci*

Tomato yellow leaf curl virus was invaded Japan in 1996. IPM system was developed; prevention of invasion using insect screen of less than 0.4mm mesh, near ultraviolet ray-absorbable (UVA) film, yellow sticky tape and/or resistant variety.

#### 3. Artificial selection for reduced flight ability of ladybird beetle, *Harmonia axyridis*, and the evaluation as biological control agent

The ladybird beetle with low flight ability was artificially selected in order to reduce the escape before the reduction of the aphid population. After 20 selections in each generation, flightless strain can be selected, and it reduced the aphid population more effectively than normal strain.

4. Real-time prediction of long term migration of whitebacked planthopper, *Sogatella furcifera* and brown planthopper *Nilaparvata lugens*

Whitebacked planthopper and brown planthopper do not overwinter in Japan, and they migrate over the sea in rainy season everyyear. New prediction system using the meteorological forecast data was developed. It can predict well the time and amount of migration.

5. Control of the sugarcane click beetle, *Melanotus okinawensis*, by mating disruption using synthetic sex pheromone

Sugarcane click beetle feed the root of sugarcane and yield of sugarcane decreases. Larval period is very long (2-3 years). Control experiment was conducted in Minami-Daito island (31km<sup>2</sup>) from 2001. Synthetic sex pheromone was distributed all area of the island. The density decreased gradually from 2002, and the damage decreased gradually.

6. Management of paddy fields for conservation of biodiversity

Paddy ecosystem involves not only paddy field but also footpath between paddy field, waterway, reservoir, copse and so on, and is the most important ecosystem in Japan. Various species of animals live in paddy ecosystem. Management system of paddy fields for conservation of biodiversity in paddy ecosystem is examined.

7. Identification of termite egg recognition pheromone of *Reticulitermes speratus* and the trial for control using dummy egg

The antibacterial protein lysozyme is identified as the termite egg recognition pheromone. It strongly evokes egg-carrying and -grooming behaviors of workers. Trial for control using dummy egg on which insecticide is applied is examined.

8. Trial for the eradication of sweetpotato weevil, *Cylas formicarius*, by sterile insect technique

Sweetpotato weevil is the alien species and distributed only in southern islands. Eradication experiment by sterile insect technique is conducted in Kume island (55km<sup>2</sup>) from 2001. The population decreased to near zero and the eradication will be achieved in the near future.

## Entomological Society of China: A brief introduction

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The Entomological Society of China (ESC) is the largest non-government organization in the world serving the professional and scientific needs of entomologists and people in related disciplines.

1. Founded in 1944, the ESC has more than 13800 members affiliated educational or research institutions, health agencies, private industry, and the Chinese government. Members are researchers, teachers, extension service personnel, administrators, marketing representatives, research technicians, consultants, students, and hobbyists.

2. The ESC is a not-for-profit professional society governed by a board comprised of members. ESC is affiliated with the China Association for Science and Technology and its headquarter is attached to the Institute of Zoology, Chinese Academy of Sciences, Beijing.

3. The ESC holds together members and organizes various academic activities in promoting the development of science and technology in the fields of entomology. The society endeavors to popularize scientific knowledge and plays an advisory role in solving important problems related to insects and in entomological theories. The purpose of the society is to promote entomology for the advancement of science and the benefit of society through: scientific and professional communications, outreach on science and public policy, program development, continuing education, and fostering interest in entomology.

4. ESC is vivid in international affairs and has wide relationship with many foreign societies and institutions. Now ESC has established bilateral and multilateral cooperation with the Convention of Biological Diversity, the International Society

of Entomology, the Asia-Pacific Entomological Association, and etc.

5. The Supervisory Council (Governing Board) makes important decisions and carries out essential functions of the society. Its members, volunteering their time and energy, are elected by the members for every five years.

6. Activities of the ESC can be roughly grouped into following categories: meeting, programming, consulting and popularizing on entomology. The premier event of the Society is its Annual Meeting.

7. The society have 6 working committees (Science Popularization, Technical Consulting, International affairs, Organizing, Youth, Financial), and 12 special academic committees (Insect Faunistics and Systematics, Insect Physiology and Biochemistry, Ecology, Insecticide and Toxicology, Agricultural Entomology, Forest Entomology, Medical Entomology, Biological Control, Insect Resources, Urban Entomology, Acarology, and Butterflies).

8. The ESC offers journals that provide unsurpassed coverage of the broad science of entomology. The society publishes scientific journals, such as *Acta Entomologica Sinica*, *Insects Science*, *Chinese Journal of Applied Entomology* (former Entomological Knowledge), *Acta Zootaxonomica Sinica*, and *Acta Parasitologica et Medica*.

9. The ESC is seeking for new routines to meet the needs of developments of sciences, communities, and economy.

## **Current status and future of applied entomology in Taiwan**

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Taiwan is an island located in the south-east of China (20°30"N, 121°00"E), and the Tropic of Cancer runs through the middle of the island. Total area of Taiwan is about 36,000 sq. km with 394 km long and 144 km wide at its broadest point. The mountain ranges occupy almost half of the island, more than 200 peaks elevate over 3000 m, and the tallest peak is Yu-Shan (Jade Mountain) with 3952 m. In general, Taiwan has a marine climate and varies widely by season in the Northern part and the mountain areas however, in the South, it belongs to the tropical belt and is warm and humid all year. These diverse climate patterns create the extreme diversity of insects in Taiwan, of course including all kinds of insect pests. Here, I try to make a brief introduction to how we study and control in insect pests in Taiwan.

### **Entomological research related government organizations**

Mainly, two government departments, *i.e.*, the Bureau of Animal and Plant Health Inspection and Quarantine (BAPHIQ) and the Centers for Disease Control (CDC), are in charge of insect pest-related study and control in Taiwan. Both are the major providers of research funding to support study on all aspects of applied entomology; however, the former is responsible for control of animal and plant diseases and pests and plant health inspection and quarantine (agriculture entomology); however, the latter is responsible for prevention, control, survey and research of various communicable diseases that are mostly related with the public health (medical entomology). Besides, the National Science Council (NSC) provides funding mainly for basic research.

### **Entomology study in Universities and Research institutes**

There are only two “Department of Entomology” in Taiwan, one is at the National Taiwan University, and the other is at the National Chung University.

In addition, there are two plant protection related departments as well, *i.e.*, “Department of Plant Medical Science, National Pingtung University of Science and Technology” in Pingtung County and “Department of Biological Resources, National Chiayi University” in Chiayi County. Besides teaching, all aspects of entomology-related research projects are held as well. Additionally, there are many entomologists scattered in different university, especially in medical schools for medical entomological research.

Under the Council of Agriculture (COA), there are several agriculture research institutes are responsible for agriculture research including insect pest control (applied entomology), such as (1) Taiwan Agricultural Research Institute (ARI) and its experimental branches: the key agricultural research institute in Taiwan, (2) Taiwan Agricultural Chemicals and Toxic Substance Research Institute (TACTRI): the institute is responsible for developing pesticides and plant protection technologies, monitoring pesticide residues and toxic substances in agricultural products, providing technical services, and establishing evaluation methods and guidelines to control pesticides, and (3) seven “District Agricultural Research and Extension Stations” located in Taoyuan, Miaoli, Taichung, Tainan, Kaohsiung, Hualien and Taitung Districts, respectively. These Stations are responsible for the research and extension works which are according to the regional difference, as well as (4) Endemic Species Research Institute and (5) Taiwan Forestry Research Institute.

### **Current status and future of applied entomology in Taiwan**

All aspects of the entomological research are going in Taiwan, and there is no way to clearly introduce all of them; therefore, only main directions are highlighted as the following:

(1) In agriculture-

- a. Key targeted species- oriental fruit fly (*Bactrocera dorsalis* (Hendel)), melon fly (*B. cucurbitae* Coquillett), common cutworm (*Spodoptera litura* (Fabricius)), and…….etc.
- b. Control methods-
  - i. Chemical control- it still is the key method currently.
  - ii. Nonchemical control- attractants (pheromones), natural enemy, microbial control,…….etc.
- c. Insect vectors on transmission of plant diseases.

- d. New technique- use of wireless sensor network (WSN) technology to monitor the insect population.
- (2) In public health- medical insects
  - a. Key targeted species- *Aedes aegypti*, *Ae. albopictus*, *Culex quinquefasciatus*, and...etc.
  - b. Important issues-
    - i. Insect-borne diseases- e.g. Dengue fever
    - ii. Zoonotic diseases- e.g. Japanese encephalitis
    - iii. Nuisance insects- e.g. biting midge (*Forcipomyia taiwana*)
  - c. Control methods: similar to (1) b.
- (3) Prevention, invasion and control of exotic insect pests-
  - a. Plant quarantine inspection- application of molecular biotechnology, such as PCR and microarray, to detection and identification insect species.
  - b. Invasion and control of the imported fire ant, *Solenopsis invicta*, and the erythrina gall wasp, *Quadrastichus erythrinae*.
- (4) Insect biodiversity and conservation-
  - a. Conservation species of insects in Taiwan
  - b. Firefly restoration
- (5) Application of biotechnology on insects-
  - a. Use of insect as bioreactors to produce useful proteins.
  - b. Use of transgenic insect to control insect pests.

## **Current status of entomological research in Malaysia**

**Mohamad Roff, M.N.<sup>1</sup> and Sivapragasam, A.**<sup>2</sup>

<sup>1</sup>Malaysian Agricultural Research and Development Institute, P.O. Box 12301, GPO, 50774 Kuala Lumpur, Malaysia and <sup>2</sup>CABI Southeast Asia Regional Center, P.O. Box 210, 43400, UPM Serdang, Selangor, Malaysia

Agriculture remains an important sector of Malaysia's economy contributing 12 percent to the National GDP and providing employment for 16 percent of the population. The sector can be primarily grouped into three sub-sectors. The agro-industrial sub-sector comprising the oil palm, rubber and cocoa industries which mainly serves the export market. The food sub-sector includes rice, fruits and vegetables, which largely serves domestic consumption and also for export market. The third sub-sector, the miscellaneous group, consists of floriculture, tobacco, pepper, coconuts, sugarcane, cassava, sweet potato, maize, tea and coffee, which cater both the domestic and export markets. Export earnings of the agro-industrial sub-sector from palm oil, rubber gloves, and cocoa posted a record of RM113.3bil in 2010, a 24% jump from 2009. The production of fruits and vegetables are targeted to reach 2.56 million tonnes and 1.13 million tonnes, respectively, by 2011. Starfruit, pineapple, papaya, melons, banana and jackfruit are gaining interest among farmers. Most of these fruits are to cater for the export market. Rice is a strategically important industry in Malaysia. Rice cultivation in Malaysia is closely associated with the rural population and traditional farmers, but in the last 30 years, rice has been transformed into a commercial crop. These are the crops that are considered important in generating income and creating jobs for the country. Therefore, these crops need to be protected from infestations by insect pests. For this, the government has provided substantial funding for entomologists to carry out research and development to safeguard these crops.

The favorable year-round climate in the tropics promotes not only vigorous plant growth but also the proliferation of insect pests. This poses a serious challenge to plant protection. Malaysia faces several serious insect pest problems, viz., the rhinoceros beetle, bagworms and nettle caterpillars in oil palm; brown



plant hopper, *Nilaparvata lugens*, stem borers and leaf feeders in rice and the cocoa pod borer (*Acrocercops cramerella*) and the mosquito bug, *Helopeltis theobromae* problem in cocoa. The Ministry of Agriculture and Agro-based Industry (MoA-ABI) is the focal Organisation handling agriculture in Malaysia. Under MoA-ABI, plant protection is carried out by two main agencies, namely the Department of Agriculture (DOA) and the Malaysian Agricultural Research and Development Institute (MARDI). DOA provides mainly extension service functions and MARDI is responsible for R&D researching ways and means of managing insect pests. Other governmental agencies involved in plant protection include the Malaysian Rubber Board (MRB) and the Malaysian Palm Oil Board (MPOB). In addition, at least four universities, private sector of several large plantation groups (e. g. Dunlop Estates, United Plantations, Sime Darby, Highlands and Lowlands, Kuala Lumpur Kepong) and agrochemical companies (Syngenta, Bayer, Du Pont), which are involved in the production and marketing of pesticides, also carry out various aspects of R&D in plant protection. The list of researchers working in the area of entomology in the public institutions and universities is shown in Table 1. The universities in Malaysia conduct fundamental types of research ranging from molecular entomology to cutting-edge entomological research while the public R & D institutions carry out research to solve specific pest problems or to enable the understanding of the underlying causes of pest problems.

In Malaysia, for more than 50 years, pesticides have been used to protect agricultural crops from pest damage. While chemical control of pests remains an important means of plant protection, there is a recent switch of emphasis from pesticide-dependent methods to a multidisciplinary approach using non-pesticidal methods. The use of non-pesticidal methods to control insect pest in Malaysia is as old as agriculture itself. This method has been well accepted by the agricultural sectors especially in plantation crops such as oil palm. Being environmentally conscious, the MoA-ABI encourages the development of non-pesticide methods in controlling insect pest. Both DOA and MARDI have designed programs to implement non-pesticidal methods in all crops, with notable successes particularly in rice, vegetables (cabbage and chilli) and fruits (to control fruit flies).

Non-pesticidal methods are sound to the environment because they are usually based on ecological principles. The current strategies of insect pest management are to maximise the role of biologically-based technologies for sustainable pest management. Research is currently directed mainly on the development of resistant crop variety, ecological engineering and biological control methods. However, in Malaysia, much efforts are devoted to promote biological control as a foundation of non-pesticide methods to control pest problem.

World trade in agricultural commodities is growing at a rapid rate. As agricultural trade is increasing, the risk of introducing exotic insects into new areas where they may become plant pests increases. Malaysia is also involved in some of the international cooperation programs in the area of plant quarantine. The Department of Agriculture, which is recognised by the Food and Agriculture Organisation (FAO) as the National Plant Protection Organisation (NPPO), is responsible for conducting negotiations in requesting market access of Malaysia's products into foreign countries. Prior to that, quarantine protocols need to be developed based on terms and conditions stipulated for entry into the importing nation's market. Currently, research in this area is actively pursued in MARDI. The protocols developed include the irradiation of rambutan and pineapple for disinfestations against mealybug and irradiation of jackfruit and papaya against fruitfly; vapour heat treatment (VHT) of papaya and mango against fruitfly and VHT of pineapple against mealybug, cold treatment of mangoesteen and carambola against fruitfly; fumigation of pineapple against mealybug, the use of the systems approach for the durian fruit borer and fruitfly in jackfruit. There is also a protocol developed for an area wide fruitfly free-zone for carambola cultivation.

Insects are always associated with negative effects on the agricultural industry. The many benefits that insects offer are often overlooked and underestimated. There is a need to link the potential of insects to economic prosperity. Entomologists in Malaysia are currently looking into the potential use of cricket as animal diets. Although the idea is not new, the nutritive value of cricket as feeds for poultry has been recognized for some time whereby studies have demonstrated that insect-based diets are cheaper to those based on corn.

Other future areas of research in entomology that are suggested in using insects as bioresources. These include the following:

- Production of natural dyes

The demand for natural dyes is constantly increasing with an increase in awareness of the public on the ecological and environmental problems associated with synthetic dyes.

- Bioindicators in the environment

The use of insects as bioindicators can be considered as applied entomology. Its primary goal is to use insects as bioindicators to monitor the impact of ecological disturbances and to use this knowledge in the management of the ecological system e.g. to assess pollution.

- Insects as pollinators

Studies on the crucial role of insects as pollinators has recently been emphasised due to vagaries of yield in cultivated crops, especially those crops that are subjected to indiscriminate pesticide use or those grown under protected cultivation. One good example of a pollinator that helped the Malaysian oil palm to achieve high yields is the weevil *Elaeodobius kamerunicus*.

- Use in eco-tourism

Insects are providing various opportunities in the eco-tourism sector. In Malaysia, the popular Rajah Brooke birdwing butterfly, (*Trogonoptera brookiana*) and the lamphyrid fireflies (*Pteroptyx tener*) are natural attractions for both local and foreign tourists.

Malaysia's mega-biodiversity provides numerous resources from insects that are also vast and diverse. With their multiple utilities, insects have been providing constant services to the mankind as other resources. Establishment of mass breeding insectaries with modern facilities, such as raising them using artificial diet or through biotechnological intervention, could provide a hope for income generation. It is a high time that researchers recognise the manifold utilities that insects provide and begin to expand their utilization.

■ 초청연사 ■

**Table 1.** List of Entomologists in public research institutions and universities in Malaysia.

Institution	Name	Discipline/Area of interests	Email address
Malaysian Agricultural Research and Development Institute	Mohamad Roff Mohd. Noor	Virus-vector relationship and Pest Management of fruit and vegetable crops	roff@mardi.gov.my
	Ithnin Badri	Pollinator and biocontrol of fruit crops	ithninb@mardi.gov.my
	Mohd. Norowi Abd. Hamid	Pollinator ecology, rice insect ecology and dynamics	norowi@mardi.gov.my
	Sulaiman Zulkifly	Quarantine Treatment and Biocontrol of fruitfly	zieman@mardi.gov.my
	Saiful Zaimi	Applied entomology vegetable crops	sfzaimi@mardi.gov.my
	Suhana Yusof	Quarantine treatment and Insect systematic	suhanalr@mardi.gov.my
	Mohamed Rani Mat Yusoh	Insect nutrition and Ecology	mrmy@mardi.gov.my
	Rosliza Jajuli	Insect taxonomy	rosliza@mardi.gov.my
	Siti Noor Aishikin Abd. Hamid	Insect pathology	ctaikina@mardi.gov.my
	Mohd Yusri Zainuddin	Biocontrol	yus@mardi.gov.my
	Mohd Masri Sariman	Biopesticides	mohdmasri@mardi.gov.my
	Mohd Shahrizal	Insect ecology	shad@mardi.gov.my
	Tan Siew Bee	Pest management	sbtang@mardi.gov.my
	Maisarah Mohd Saad	Insect toxicology and Host plant resistance	mysara@mardi.gov.my
	Wan Khairul Anuar Wan Ali	Pest management	wkhairul@mardi.gov.my
Malaysian Rubber Board	Mohd Muaz Samsudin	Applied entomology	muaz@lgm.gov.my
Malaysian Palm Oil Board	Norman Kamarudin	Biology and ecological of <i>Oryctes rhinoceros</i> and Hymenopterous parasitoids of bagworms	norman@mpob.gov.my
	Ramle Moslim	Biological control of oil palm bagworm and oil palm rhinoceros beetle	ramle@mpob.gov.my
	Zulkefli Masijan	Pollinator weevil <i>Elaeidobius kamerunicus</i> , parasitoid and predator of oil palm pest	zulmas@mpob.gov.my

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Institution	Name	Discipline/Area of interests	Email address
Malaysian Cocoa Board	Azhar Ismail	Applied Insect Ecology	abi@koko.gov.my
	Alias Awang	Entomology	aliasawang@koko.gov.my
	Meriam Mohd. Yusof	Entomology and Taxonomy	meriam@koko.gov.my
	Navies Maisin	Entomology	navie@koko.gov.my
Universiti Malaysia Sarawak	Fatimah Abang	Systematic entomology	fatim@frst.unimas.my
	Sulaiman Hanapi	Pest management	sbh@frst.unimas.my
Universiti Kebangsaan Malaysia	Idris Ghani	Pest management, Taxonomy and Biocontrol	idrisgh@ukm.my
	Wee Suk Ling	Insect chemical ecology and Applied entomology	slwee@ukm.my
	Ng Yong Foo	Insect ecology and systematic	ng_yf@ukm.my
	Izfa Riza Hazmi	Insect systematic	ladies_ifza@yahoo.com
	Johari Jalinas	Insect pathology	johari_j@ukm.my
	Salmah Yaakop	Insect ecology and Applied entomology	salmah78@ukm.my
Universiti Putra Malaysia	Dzolkhifli Omar	Pesticide application techniques and Insect toxicology	zolkifli@agri.upm.edu.my
	Rita Muhamad Awang	Applied entomology	rita@agri.upm.edu.my
	Nur Azura Adam	Insect systematic and Applied entomology	Nur_azura@putra.upm.edu.my
	Law Yao Hua	Entomology	yaohua@putra.upm.edu.my
Universiti Malaya	Fauziah Abdullah	Insect behaviour and Chemical ecology	fauziah@um.edu.my
	Azidah Abdul Aziz	Insect Systematic and Applied entomology	azie@um.edu.my
	Mohd Sofian Azirun	Insect toxicology	sofian@um.edu.my
Universiti Sains Malaysia	Abu Hassan Ahmad	Applied entomology	aahassan@usm.my
	Che Salmah Md. Rawi	Insect ecology	csalmah@usm.my
Universiti Teknologi MARA	Fauziah Ismail	Pest Management	fauziah@salam.uitm.edu.my

## **Current status and future of applied entomology in USA.**

**Thomas A. Miller**

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President Ahn, fellow delegates and fellow entomologists, I thank you for the invitation to join you today and bring you greetings from the Entomological Society of America (ESA). The current President, Ernest Delfosse also sends greetings to President Yong-Joon Ahn and members of the Korean Society of Applied Entomology. He wishes you good luck with your meeting and continued success. Rarely do we get a chance to greet officially so many entomology societies at once. So I extend the same cordial greetings to The Australian, Taiwan, Japanese societies and the Plant Protection society from Malaysia.

My first introduction to Korean entomology was to learn that there are two societies, the Korean Entomology Society and the Korean Society of Applied Entomology. That reminded me that in America in the early days there were also two societies, the American Association of Economic Entomologists (founded in 1889) and the Entomological Society of America (ESA) that first met in 1906. These two separate societies merged in 1953 to become the present ESA.

However, the first organized effort in economic (applied) entomology dates from 1792 when the American Philosophical Society appointed a committee to collect materials for a natural history of the Hessian fly, ravaging wheat fields. At this time George Washington was the President and Thomas Jefferson was Secretary of State. Thus since the beginning of the country, there has been a critical need for applied entomology.

### **Entomological Society of America.**

Today the ESA with 6410 members (2010 figure) is the largest organization in the world serving the professional and scientific needs of entomologists and people in related disciplines. The membership represents educational institutions, health agencies, private industry and government. Members are researchers,

teachers, extension service personnel, administrators, marketing representatives, research technicians, consultants, students and hobbyists (From the website: [http://www.entsoc.org/about\\_esa](http://www.entsoc.org/about_esa)).

Our society is a mixture of participants from those with a pure love of insects to those responsible for studying insects as pests or beneficial partners in agriculture and public health. We support a well-established number of peer-reviewed journals.

Besides the ESA, many vector entomologists belong to the American Mosquito Control Association and the American Society of Tropical Medicine and Hygiene founded 1903 and the subspecialty in urban entomology has its own society and annual meetings. I also list the CAPCA in California, our local society of Pest Control Advisors (PCA) as an example of a local professional industry group, one of many in the country. In addition there is a national Integrated Pest Management organization with its own annual national meeting and literally dozens of local entomology societies. I will point out just two of these, the Florida Entomology Society and the Society of Southwestern Entomologists. The former has headquarters in the University of Florida at Gainesville and the latter is at Texas A & M University in College Station, Texas and both of these groups publish well-established refereed journals.

The agencies of the federal government that hire entomologists include Environmental Protection Agency (EPA), United States Department of Agriculture (USDA), Center for Disease Control (CDC), Smithsonian Institution, and US Army among others.

A recent request for proposals [**Funding Opportunity Number**: EPA-OPP-11-001] from the Environmental Protection Agency (EPA) listed the following issues in crop protection to give you a flavor of the issues being addressed in the USA:

### **Agricultural Sector**

Agricultural issues involving pesticides for which IPM (Integrated Pest Management) advancements are sought:

1. Resistance management

2. Water quality and runoff issues
3. Pollinator protection issues
4. Endangered species protection
5. IPM approaches for controlling rodents and predators in livestock operations
6. Urban/rural interface and volatile pesticides
7. Repeating or priority emergency exemption uses: Liverwort on Commercial greenhouses, **Emerald Ash Borer** in Woodlots, Nematodes on Raspberry, Green Mold on Mushrooms, Blight on Walnut, **Varroa Mite** on Raised Honeybees, **Thrips** on Onions, Fire blight on Apples, **Billbugs** on Orchard grass, **Grass mites** on Timothy, *Phytophthora* on Ginseng, **Grasshopper** on Alfalfa, **Fly control** in Mushroom houses, and **Exotic Fruit Fly** larvae-drench use pattern.
8. Emerging Pest Management Gaps: **Invasive Stink bugs** on Tree fruit, **Lygus bugs** on cotton, **Asian Longhorn Beetle** in Forestry, Citrus Canker on Grapefruit, *Septoria citri* on Citrus, and Bacterial blight on Fruiting vegetables.

Of the insect pests in the list above, half are invasive species.

USDA major invasive species list also gives a clue of current insect pest problems:

Asian Citrus Psyllid

Asian Longhorned Beetle

Citrus Greening

Emerald Ash Borer

European Grapevine Moth

European Gypsy Moth

False Codling Moth

Light Brown Apple Moth

Mediterranean Fruit Fly

Mexican Fruit Fly

Oriental Fruit Fly

Sudden Oak Death

<http://www.aphis.usda.gov/hungrypests/asianCitrusPsyllid.shtml>



In California alone our state entomologist, Bob Dowell, reports that historically a new insect or other pest or disease arrives every 60 days. Usually after they arrive, they remain. Eradication attempts have been made in the past, but the success rate is low. Therefore, most of our time is spent learning how to deal with invasive pests.

Possible the greatest current threat to US agriculture is citrus greening or huanglongbing disease of citrus caused by a pathogen transmitted by Asian citrus psyllid, another invasive species. Both are present in Florida threatening the entire citrus industry there and in Texas and the insect vector is now present in California.

Besides Invasive Species, the main entomology issues facing us today are plant protection, public health, food security and habitat loss creating endangered species and threats to biodiversity. Besides these issues mosquito control demands constant attention and bed bugs, *Cimex* sp., have become a national epidemic also attracting attention.

### **Colony Collapse Disorder.**

The United Nations recently called more attention to the problem of decline of honey bees globally and American remains very concerned about the problem. Unfortunately there is no widely accepted explanation for Colony Collapse Disorder, as it is currently called. The phenomenon is similar to disappearing frogs and coral reefs and all of these events may be related to a mixture of causes including climate change and habitat loss all adding up to the sixth mass extinction event in the history of earth.

### **Dengue in Key West Florida.**

In this context, dengue fever has become established in Key West Florida. Reports suggest that 5% of the population of the area now test positive for the dengue virus one serotype. Because the vector mosquito, *Aedes aegypti*, yellow fever mosquito, cannot be eradicated with existing insecticide methods, new methods of control are urgently needed before the situation grows worse. This is a tall order since new ways to control insects are rare.

### **Genetically modified insects in SIT.**

The Oxitec Company, Oxford, UK, developed a genetically modified (GM) mosquito with the RIDL® gene that is passed on to offspring as a lethal trait in the absence of tetracycline and adopted a male only release (males do not feed on blood and therefore do not transmit dengue virus) for a new Sterile Insect Technique (SIT) strategy. The first field trials using the RIDL mosquito in SIT reported an 80% suppression of the wild population of yellow fever mosquito. News was posted of this result in fall of 2010 by the government of the Cayman Islands. This was followed by a loud outcry from environmental groups about safety, insufficient notification (the government of the Cayman Islands did local surveys and announcements, but apparently did not notify everyone on the islands), and the need for more testing.

The Ministry of Health in Malaysia then conducted field trials there of the same mosquito to determine ability to compete with wild types (December 2010 to Jan 2011). The government of Brazil has announced similar trials there.

The Florida Keys Mosquito Control District (FKMCD) applied for use of RIDL mosquitoes in an SIT program there based on the Cayman Islands results. By spring of 2011, the application has been under review for a year and a half with no sign of a decision being made.

FKMCD is asking to use RIDL mosquitoes in SIT because they cannot completely control the vector insects with present insecticide-based methods and local elimination of wild populations of yellow fever mosquito using RIDL mosquitoes in SIT was shown to be possible; it is the only certain way to eliminate the vector of the dengue virus. As populations of pest insects decline in number, SIT becomes more efficient and effective; whereas, insecticide-based methods become less so. Short of vaccine development, the people in Key West are likely to be visited by more virulent forms soon. It is a matter of time.

Last month, March, 2011, the government of Paraguay declared a state of emergency when the most recent dengue outbreak there caused 22 deaths and affected hundreds of thousands overwhelming the health care system. We have been warned for some years that this situation will get worse.

### **Symbiosis.**

One of the most rapidly growing parts of entomology (indeed biology) is symbiosis. This was caused by a technological breakthrough in molecular biology starting with the discovery of the polymerase chain reaction (PCR) method. Before we could not identify 95% of symbionts; today we can identify all of them. By symbionts I mean microbes, but the term includes fungi and must also now include viruses. Two of the Plenary Speakers out of six at the next Entomology Congress will cover different aspects of symbiosis. This is an illustration of how important the topic has become.

To put the topic into perspective the adult human body has a certain number of cells. The number of bacteria in and on the human body is ten times that number. The number of viruses associated with the human body is ten times the number of bacteria and we haven't mentioned fungi or other life forms.

This exact same situation applies to insects as well and it involves a very close co-evolutionary development. Endosymbiont is a special term reserved for intracellular symbionts, usually, but not always bacteria.

It is becoming clearer every day that we will not fully understand the biology of insects until and unless we understand the symbionts including endosymbionts. Traditionally we think of symbionts as providing vital nutrients for the host insect, but today we appreciate that much more is involved, host plant selection, adaptation, cryptic coloration, immune reactions, resistance to parasitism and much more.

This field is very diverse in insects where we find a great variety of these interactions.

My wife and I had the rare honor to be consultant and observer at a working session of the entomology section of the International Atomic Energy Agency (IAEA) in Vienna during February 2011. The purpose was to help an elite group of entomological colleagues draft a request for proposals to develop probiotic methods to improve fitness in insects used in the SIT programs IAEA consults for around the world.

Symbiosis has come far in a short time. I was impressed with the IAEA activities and personnel and that SIT was now being applied to locally eliminate tsetse, various tephritid fruit flies, codling moth, pink bollworm and possibly light brown apple moth and with plans to develop SIT for mosquito control. SIT is possibly the most sustainable insect control method known. It does not involve residues or importation of natural enemies; it has no side-effects of concern to biodiversity and Jorge Hendrichs, of International Atomic Energy Agency, reminded us that due to the broad effects of radiation, multiple sterile elements are produced making it very difficult for target insects to develop resistance to the method.

In September of 2010, we were honored to participate in the latest workshop on Applied Arthropod Symbiosis held at the Greek Orthodox Academy in Kolymbari, Crete, Greece. At the meeting, Daniele Daffonchio from University of Milan reported finding a symbiotic control method to control American Foul Brood Disease of bee hives based on competitive displacement and applied in sugar water to be spread by worker bees. In this project he partnered with colleagues at the University of Tunis in Tunisia. Maria Perotti from University of Reading, UK reported on the new field of acarology-based forensic entomology; the “finger-printing” of humans based on the unique populations of skin mites they possess. And finally Scott O’Neill from Queensland University reported on the most advanced use of *Wolbachia* bacteria to control wild yellow fever mosquito populations known. His is not a genetic modification method, but a forced symbiosis of one *Wolbachia* strain into *Aedes aegypti*. The process of obtaining approvals for this first-ever release was lengthy and precedent-setting.

### **Biotechnology**

It was no accident that the genome of an insect was sequenced (*Drosophila melanogaster*) before that of humans. Insects continue to provide models for scientific research useful as models in medicine and agriculture. Last month I attended the 2011 Philip Abelson Symposium on Alzheimer’s disease of aging in humans at AAAS headquarters in Washington DC. One of the most critical discoveries mentioned in that symposium was the heat shock promoter from *Drosophila melanogaster*. This factor has since been discovered to be ubiquitous in eukaryotes performing the vital role of producing chaperone proteins that fold

proteins properly. Improper folding leads to plaque build-up in the brain causing Alzheimer's disease and creates prions responsible for mad cow disease or bovine spongiform encephalopathy.

Genetically modified crops have been revolutionizing agriculture with new properties of herbicide and insect resistance that makes weed and insect control more efficient than ever before. Entomology has been left behind by this technology except in GM silkworms for industrial applications.

The pink bollworm was genetically altered in 1998 (a year before the silkworm) for the purpose of producing a conditional lethal strain that could be used in the Sterile Insect Technique (SIT). From the moment we had a conditional lethal strain soon after until today, regulatory approval has not been given to use this new technology.

And yet SIT is one of the most successful area-wide methods known and used all over the world based on radiation to induce sterility. By replacing radiation with conditional lethal genes, entomologists calculate that the GM SIT insect would be more competitive with wild type insects in the target populations.

In addition to the use of GM *Aedes aegypti* yellow fever mosquitoes for area wide control of dengue fever in the SIT strategy, the USDA was developing a GM screwworm fly for use in their SIT program in Panama. Upon hearing of this last January, federal regulatory officials realized that the regulation of a GM insect that is a cattle pest had no regulatory guidelines.

Regulatory approval of the use of GM insects is a major challenge in entomology in the USA. It is a challenge because of a lack of precedent and because of lack of widespread public support. There is a need for public education and for successful examples.

IAEA entomology activities are not at all integrated into mainstream entomology as it exists in all of the different countries. And I wonder if there was some way that entomology at IAEA could be brought more central into the profession. Perhaps it could be integrated more into the International Congress of

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Entomology. I am working with President Byung-Jin Kim of ICE2012 (International Congress of Entomology, 19-25 August 2012, Daegu, Korea) to see what can be done.

Many thanks for your attention and good luck with the KSAE meeting.

## Current status and future of entomology in Australia

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Australia has a land surface area of 7.5 million km<sup>2</sup>. It has been isolated for millions of years and the flora and fauna are largely endemic. The entomological fauna is poorly known; for example it has been conservatively estimated that Australia has about 200,000 species of insects of which only 60,000 have been described. Entomological research in Australia includes farm trials by consultants for control of insect pests, the development of Integrated Pest Management involving the use of insecticides, natural enemies, plant resistance and cultural methods. However, it also includes more basic research into biology, behaviour, ecology, genetics and biodiversity of insects. For some intractable pest problems the more basic research contributes to improved pest management as well as to other important applications. There is public interest in managing the environment more sustainably and insects are relatively easy to use as a biodiversity measure to estimate the impact of disturbance on conservation and the success of rehabilitation. I will provide examples to demonstrate different applications of entomological research in Australia.

Australia has a single national Entomological society, whose emblem is the bulldog ant, *Myrmecia gulosa*. It currently has about 500 members, and publishes a journal, *Australian Journal of Entomology*. There are also a number of regional entomology societies, several of which publish journals.

### **Pest control**

Insecticide use for pest control in Australia is increasing. A number of the most common agricultural pests like the budworm *Helicoverpa armigera*, diamondback moth *Plutella xylosella*, redlegged earth mite *Halotydeus destructor*, the lesser grain borer *Rhizopertha dominica*, a pest of stored grain, and sheep blowfly *Lucilia cuprina*, have developed resistance to insecticides. Research has

been carried out into the mechanisms of resistance, and ways to reduce the spread of resistance across Australia.

Sprays are applied several times during the year when pests are observed. *Halotydeus destructor* a pest of annual pastures actively feeds during the winter, and spends the summer as a diapausing egg. The mites damage seedlings at the break of season in autumn. A single spray in spring timed to catch the mites before they produce diapauses eggs results in 96% mite control eight months later in autumn, giving substantial increases in numbers of seedlings for annual crops and pastures.

Research is used to develop new strategies that reduce dependence on chemicals, and to utilise combinations of treatments through Integrated Pest Management. Enhancing the impact of natural enemies is one such treatment. Biological control of silverleaf whitefly, *Bemisia tabaci* biotype B has been demonstrated in the Bundaberg region of Queensland with the deliberate introduction of an exotic wasp parasitoid, *Eretmocerus hayati*. Biological control is also being used to control environmental weeds in areas of natural vegetation where herbicides cannot be used. Bridal creeper is being controlled by the combination of an insect and a fungal pathogen.

Most pest populations move beyond one field or farm and there is increasing awareness that control requires Area Wide Management across landscape mosaics including crops, native woodland and forest habitats. A CSIRO group in Brisbane has been investigating the concept of Pest Suppressive Landscapes (PSL), resulting in lower pest densities in crops for longer, and which have less variability in population cycles. It is necessary to know where in the landscape the pests and predators are. Crops are more of a source for pests while including heath and woodland native plants favour the natural enemies.

### **Medical research**

Dengue fever is a human disease caused by a virus that is transmitted by the bite of an infected mosquito. Dengue occurs throughout the tropics and incidence rates are increasing. *Aedes aegypti* are the most important vector, and because of their close association with humans they are hard to control. Older insects are important for transmission, and scientists at the University of Queensland have successfully transferred a life shortening strain of a bacterium, *Wolbachia*, into *A. aegypti* halving the adult life span in the laboratory. The strain also interferes



directly with dengue transmission. They believe that targeting mosquito age and dengue transmission with inherited *Wolbachia* may be a valuable strategy to reduce the transmission of pathogens such as dengue virus. Currently through a large collaborative effort between the University of Queensland, Monash University, The University of Melbourne, James Cook University and the Queensland Institute of Medical Research the *Wolbachia* mosquitoes are being bred up in glasshouses in NE Australia for evaluation of the strategy in selected small field sites. Another aspect of entomological research affecting humans is where detailed knowledge of the development rates of carrion flies is used to predict the time of unexpected human deaths at the Forensic Science Centre, University of Western Australia.

### **Ecology**

Some species maintain restricted distributions while others become more widespread pests. A combination of taxonomic and genetic work using *Drosophila* species as a model by scientists at the University of Melbourne has found that *Drosophila* with narrow distributions seem to lack genetic variation in key traits which limits their ability to extend their current range whereas other species showing wide ranges of resistance to dessication and cold and have much wider distributions.

Seasonal conditions can be important predictors of pest abundance. For locusts good autumn rains can lead to the build up of populations that have the potential to invade the southern farming systems. Switching phenotypes from solitary to gregarious forms has been investigated in the desert locust by a University of Sydney group led by Stephen Simpson. When the solitary form of locusts touch the hind femur of adjacent individuals in crowds serotonin is released in the central nervous system which stimulates the transition from the solitary to gregarious form and initiates swarming behaviour. In locust swarms simple local rules, of aligning with neighbours within a radius of 20cm, are sufficient to result in large scale mass movement and the patterns seen in actual locust bands. There is a critical density for the onset of coordinated marching by desert locusts.

### **Evolution**

The Sydney group also showed that *Drosophila* are able to trade off longevity and maximum egg production by selection of different protein-carbohydrate

ratios in their diet. They will maximise fitness, as measured by lifetime egg production at an intermediate protein-carbohydrate ratio. This work is relevant also to understanding the cause of obesity in humans.

Alternative phenotypes are common in nature, and their existence is considered to be an indication of strong intraspecific competition. For example in many *Onthophagus* dung beetles there are major males with large horns and minor males with small or no horns. Male beetles develop horns to fight for access to females. Major forms with larger horns help the females bury dung and then guard the breeding tunnels. However small males who cannot compete for females adopt an alternative tactic and sneak copulations. A group at the University of Western Australia has shown that hornless males divert resources into testes growth and sperm production, so they can compete for fertilizations.

Recent research has shown a heritable variation in production of cuticular hydrocarbons (CHCs) which insects can use to select mates and recognise dominant males. When two dominant male crickets fight the losing one changes his CHC profile to that of a subordinate. Subordinates have increased expression of CHCs that the females find attractive, but the expression of CHC is costly and is traded against ejaculate quality and fertilization success. CHCs have also been shown to play a role in mate selection in *Drosophila*. The importance of CHCs in insect ecology is a rapidly developing field under study by groups at Universities of Queensland and Western Australia.

### **Biosecurity**

Australia discovers 30-40 incursions of new plant pests or diseases every year. Protection of the economy, environment and human health from the adverse effects of these incursions is the aim of biosecurity research. Web based tools help quick identification. A Pest and Disease Image Library (PaDIL) provides high quality image libraries of pests and diseases in Australia ([www.padil.gov.au](http://www.padil.gov.au)). To identify invaders it is important also to know what closely related native species there are in Australia. To help with the taxonomic backlog the Federal Government has been funding web based tools. For example the Atlas of Living Australia brings together information held in many different places ([www.ala.org.au](http://www.ala.org.au)). The Taxonomic Research and Information Network (TRIN) developed another tool which contains computer based web keys to all 640 families of Australian insects (<http://anic.ento.csiro.au/insectfamilies/>). For inter-

active help with experts microscope networks are being set up with global reach to identify insects using webcams and the internet.

### **Insects as indicators of environmental quality**

Insects are widely used as invertebrate biodiversity indicators in measuring rehabilitation from mining, and the effects of land management on biodiversity. A group at Curtin University in Perth has been developing the use of ants as indicators. Vegetation is generally considered to represent changes in the environment. A number of invertebrate groups and birds are correlated with this. However, the two groups that are easiest to detect are ants and Hemiptera, and the ants are easier to identify and are therefore used more widely.

Ants have also been used to provide a biodiversity index of the effects of disturbance over regions. Another application for this approach is a project to detect any fall in environmental quality during the life of a \$16 billion gas extraction project. Sampling protocols have been set up and 2066 species of invertebrates detected on Barrow Island. The same approaches could also help measure the impacts of global change.

### **Acknowledgements**

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## Technology for modeling and monitoring insect pests

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### **Introduction**

Monitoring and modeling of insect pest populations are two important components in the integrated pest management (IPM). Monitoring, usually implemented by sampling, provides data on density, age structure, and dispersion of a target insect population in a defined area. A synthesis of these data with economic decision levels plays an important guideline for making control decision and selecting control methods. Insect population modeling is very useful to understand the population dynamics of insects and thus can be used to evaluate different control strategies, to identify correct control timing, and to forecast future population size of a target insect pest. Therefore, combination use of these two techniques can guarantee to devise a better control strategy and action in IPM.

Monitoring methods can be classified into two categories: sampling methods and principles. Sampling methods include traps (light, pheromone, sticky, etc.), a sweep-net, visual counting, etc. Sampling principles are basically statistics and provide sampling programs such as binomial and sequential sampling.

Modeling insect populations can be approached by empirical models (statistical models), theoretical models, and simulation models.

### **Monitoring insects**

Insect sampling is usually taken because it is not possible to count every individual insect in an area. Thus, a sampling device is used to take insect samples, and then statistical methods are applied for estimation of their population size.

Light traps are one of the most frequently used monitoring devices for insect occurrence. The source of light attractant is commonly incandescent light with the long-wave radiation (green, yellow, orange) or ultra violet or black light with

violet and blue short-wave radiations. The main structure of light traps consists of an electric bulb, a funnel and a container although their size and composition can be modified. In Korea, incandescent light traps have been used to monitor rice insect pests such as the brown planthopper in rice fields.

Unlike the light trap, pheromone traps, which employ sex pheromone of a specific insect, have specificity, and thus has been increasing popular to monitor agricultural pests. Trap design, trap saturation, trap density, and trap age affect trap efficiency significantly. Thus, intensive researches have been conducted regarding trap performance to establish reliable pheromone trap monitoring programs. There are also many commercially available sex pheromones for insect pests (mostly lepidopteran insects) and traps. In Korea, pheromone traps are commonly used for monitoring insect pests in fruit tree orchards such as apple, and pear, etc.

Sticky traps are especially efficient to monitor small flying agricultural insect pests such as whiteflies. Efficiency of sticky traps depends on visual, odor or chemical factors depending on insect species. In Korea, sticky traps are commonly used for monitoring insect pests in greenhouse crops such as cucumber, tomato, and paprika, etc.

Sweep-nets are also very useful to monitor insects on many row field crops because of their convenience, efficiency and low cost. There are several sampling procedures developed, and it is important to identify the particular procedure because of their different efficacies or outputs.

Sampling programs are developed for reliable estimation of insect population with a given degree of precision, and have been studied in detail because of its importance in IPM. Population density and spatial distribution (dispersion) of a target insect species are important characteristics for developing sampling programs. Mathematical distributions such as Poisson distribution and negative binomial distribution are used to describe dispersion. More recent techniques are geostatistics, which needs construction of the semivariogram which is a graph of spatial dependence of an organism (i.e., insect), and SADIE (spatial analysis with distance indices).

Flight forecasting degree-day models are also very useful to predict the occurrence of overwintered insects. Combination use of the degree-day models and field monitoring by pheromone or light traps can be powerful for timing control of many agricultural and forest insect pests.

In this presentation, use of some sampling devices, development of sampling programs, and spatial analysis methods, and some case studies will be given.

### **Modeling insect populations**

Insect population models are developed by statistical models, theoretical models, and simulation models. Details for these approaches are found in many literatures. Of these three approaches, application of theoretical models and simulation models is being more frequently implemented. Theoretical models are based on fundamental population dynamics theory, which is rather simple and can provide insight into the causes of population changes, and predict future change of the population size. One of the merits of the theoretical models is that they are based on solid population theories. Simulation models are usually constructed according to the insect life cycle, and require more detailed mathematical descriptions for biological events. These models can be very complex, but are also useful to analyze the population dynamics. Numerous simulation models have been developed for many important agricultural and forest insect pests. In Korea, a few simulation models were developed, but more numbers of models are being developed. In this presentation, the case study will be given in detail for the population model of the peach fruit moth, *Carposina sasakii* Matsumura (Lepidoptera: Carposinidae) (Kim and Lee, 2010, 2011).

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## **Molecular approaches to insecticide resistance management and pest control**

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Pest management employs a wide range of tools and techniques to reduce pest population density for the improvement of agricultural productivity, human health issues and, environmental sustainability. A variety of synthetic and natural compounds have been widely used for pest control but extensive use of them has generated many side effects including pesticide resistance, accidental poisoning of humans and animals and environmental contamination. To achieve environment-friendly agriculture, various molecular techniques and novel concepts have been implemented in many areas related with pest management, including molecular insecticide resistance management (IRM), sterilization insect technology (SIT) and RNAi-based pest control. In my presentation, I will focus on current status and future prospects of above mentioned approaches.

### **1. Molecular IRM**

Main issues in IRM include the interpretation of resistance mechanisms and early detection of resistance frequency in the field. Rapid development of ‘omic’ technologies has accelerated the elucidation of molecular and genetic mechanisms of resistance. Genome-scale identification of the genetic components involved in insecticide detoxification allows pinpointing possible metabolic factors in resistance. Based on such information, DNA-based molecular diagnostic protocols can be developed to estimate resistance allele frequencies in the field populations of pest precisely. Several genotyping techniques, on both individual- and population-basis, include: PCR-amplification of Specific Allele (PASA), Serial Invasive Signal Amplification Reaction, Quantitative Sequencing, Real-time PASA, etc. Availability of such molecular protocols facilitates accurate estimation of initial resistance allele frequency in field populations, eventually enabling a preventive IRM prior to resistance development.

## 2. SIT

Traditional SIT based on radiation was developed in early 1950' and was successfully used for the eradication of screw-worm flies in the US. To improve sexing efficiency, recombinant DNA technology was developed to create transgenic insects by introducing a repressible 'female-specific dominant lethal' gene. Although this so-called 'RIDL' (Release of Insects carrying a Dominant Lethal) has not been approved for the field use, SIT programs will be benefited greatly in the future once this genetic protocols enabling the production of only males are applicable as in the case of the medfly. Availability of vast information on various insect genomes will facilitate finding more effective lethal genes and transposable vectors that are essential for RIDL.

## 3. RNAi-based pest control

Among transgenic approaches to insect control, transgenic plants expressing *Bacillus thuringiensis* (*Bt*) toxin have been particularly successful. Nevertheless, Bt toxin is not effective against many homopteran insects and acari pests and there are a few reported cases of resistance development. Recently, a novel technique utilizing transgene-encoded ingestible dsRNA was developed. Initial attempts were done by feeding insects with artificial diet supplemented with specific dsRNA to screen a large number of essential insect genes. In case of sucking insect pests, however, feeding dsRNA is not straightforward as in chewing insects, requiring more sophisticated membrane feeding systems or some other delivery means. Once the dsRNA delivery system established for sucking insects, a large scale screening would be possible for them to select candidate genes, of which knockdown by low levels of dsRNA is lethal. To make this exciting new technology be commercialized, however, there still remain significant challenges to be discussed.



## Application of dNA barcoding in entomogy: A case study of the superfamily tephritoidea (diptera) in Korea

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The superfamily Tephritoidea is a large group of acalyprate flies including over 7,300 described species arranged in nine families. All the tephritoid families excluding Richardiidae are represented in Korea, but their taxonomy has not been well studied. For example, a total of 80 species of the family Tephritidae are currently known in Korea, but our personal data shows that there actually are at least 150 species. Presence of highly variable or cryptic species has been hampering taxonomic progress involving this group of flies. Some genera such as *Trypeta*, *Campiglossa*, *Oxyyna*, and *Tephritis* are good examples of taxonomically difficult taxa. We find that DNA barcoding is extremely helpful to clarify such taxonomic problems. We are currently trying to barcode multiple samples for every single Korean tephritoid species. A total of 271 specimens representing 185 species have been barcoded so far. Neighbor-Joining analysis of our preliminary data shows many interesting findings that are potentially useful to resolve long standing taxonomic problems. The followings are some of our findings through the DNA barcoding analyses: 1) multiple samples for each included species were almost always clustered together showing utility for specific identification; 2) multiple species per each genus were mostly clustered together; 3) clarification of male and female association of two closely resembling new *Acidiella* species; 4) strongly support synonymy of *Sinacidia* and *Chetostoma*; 5) possible existence of two cryptic species within *Campiglossa defasciata*; 6) possible synonymy of *Dioxyyna* and *Campiglossa*; 7) possible synonymy of *Herina zojae* and *H. hennigi*; and 8) discrimination of two closely resembling *Chaetostomella* species.

**Key words:** DNA barcoding, Tephritoidea, Tephritidae, Korea, Taxonomy

## Development of Biomaterials from Insects

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Insects are the most extant organisms on the earth, because of their excellent survival ability against various environments. With development of biotechnology, insects are high potentially regarded as so useful bio-resources with other bio-diversity. We overview the status of biomaterials from insects with several cases as follows; 1) Mass production of industrial insects ... silkworm, honeybee, and some insects as pollinator and natural enemy etc. These insects have been used for mainly agricultural industry. 2) Ornamental insects ... butterfly park, insectariums, education, life-cares, eco-tour and for festival etc. 3) Bioactive substances from insects ...potential sources of novel pharmaceuticals and functional foods. Many kinds of insects are screening including traditional medicinal insects by pharmaceutical companies. Some antimicrobial peptides are also developing by self defense mechanism of insects. 4) Highly active enzymes from insect microbes ...based on the behavior and habitat of insect diversity. Several industrial enzymes were developed by the microbes isolated from insects, such as the protease 'Arazyme', xylanase etc. This is one of the hottest emerging fields in bio-industry including food, animal feed, cosmetics, bio-fuel etc. 5) Biomimetics ... structure of housing, biosensor for drug and explosive, flying mechanism, spinning of super fiber, bio-adhesives, holography, lac and wax from insects etc.

Recently, insect will be utilized for more wide and regardful fields with Convention of Biodiversity(CBD) and Access and Benefit Sharing(ABS) of Genetic Resources(Nagoya Protocol). The promotion law and institution are also activating for insect industry in Korea.

## Disruption of insect physiological processes and novel control strategies

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Molecular techniques significantly contribute to study of insect physiology. With easy access of insect genome, paradigm of physiological study has been changed analytical approach into a reverse direction from molecules to phenomena. For example, an unidentified gene of an insect species can be compared with known genes of other species. This comparative analysis provides a presumptive physiological function of the unidentified gene. Subsequent analysis of the gene function would be focused on the physiological process. RNA interference of the gene then supports the physiological function of the gene. This kind of reverse physiology approach has been used to determine novel molecular pathogenic targets of microbial pathogens, including bacteria and viruses. This presentation demonstrates reverse physiological approaches using two microbial pathogens that disrupt insect physiological processes, such as immature growth, metamorphosis, and immune responses. These studies have identified novel pathogenic molecular targets of insect pests, which would be applicable to design novel strategies on insect pest control.

### **1. Phospholipase A<sub>2</sub> as a molecular target of an entomopathogenic bacterium, *Xenorhabdus nematophila***

Phospholipase A<sub>2</sub> (PLA<sub>2</sub>) catalyzes the committed step of eicosanoid biosynthesis and releases of arachidonic acid from phospholipid at *sn*-2 position. The arachidonic acid is then oxidized by either cyclooxygenase or lipoxygenase to be transformed into variouseicosanoid compounds. Eicosanoid mediates various physiological processes including excretory process of Malpighian tubules, stimulating egg lay behavior, and mediating immune responses. Various specific eicosanoid biosynthesis inhibitors disrupt these physiological processes.

An entomopathogenic bacterium, *X. nematophila*, is a symbiotic bacterium of an entomopathogenic nematode, *Steinernema carpocapsae*. When the infective juvenile nematode enters target insect larval hemocoel through mouth, anus or spiracle, it releases its symbiotic *X. nematophila*. The bacteria then inhibit insect immune responses by inhibiting catalytic activity of PLA<sub>2</sub>. Under these immunosuppressive conditions, the bacteria multiply and facilitate their host nematode development. The immunosuppression is further analyzed in terms of action of eicosanoid mediation. Phenoloxidase (PO) activity is required for performing cellular and humoral immune response in insects. PO is synthesized only in a specific hemocyte cell type, oenocytoid. PO is formed in an inactive PO precursor, proPO, in oenocytoid. To be activated, proPO should be released into plasma. Due to lack of signal peptide, the only way of proPO to be released is cell lysis of oenocytoid, which is mediated by the action of a type of eicosanoid, prostaglandins (PGs). PGE<sub>2</sub> receptor is identified in the hemocyte EST and proved by its specific expression and ligand binding assay. Thus depression of PLA<sub>2</sub> catalytic activity by infection of *X. nematophila* inhibits biosynthesis of PGs, which prevent cell lysis of oenocytoid to release proPO and results in significant immunosuppression.

## **2. A polydnavirus as a tool of reverse physiology study**

Polydnavirus (PDV) is an insect virus symbiotic to some endoparasitoids classified into Braconidae or Ichneumonidae. It is present in a proviral form on host insect chromosome(s). Interestingly, its replication is confined in a female reproductive organ. A PDV species has been identified in Korea from a braconid wasp, *Cotesia plutellae*, and named *C. plutellae* bracovirus (CpBV), in which diamondback moth, *Plutella xylostella*, is a natural host of the wasp. Parasitized *P. xylostella* larvae suffer significant immunosuppression and fail to undergo pupal metamorphosis with extension of larval period. Genome analysis of the episomal CpBV provides at least 125 predicted genes, some of which are classified into several typical PDV gene families, such as protein tyrosine phosphatase (PTP), EP1, and vankyrin families. It also contains *Cotesia*-PDV specific gene, such as viral histone H4, viral lectin, and HTIF (host translation inhibitory factor) genes. More than 50% open reading frames are hypothetical. All these genes have been known to play a role in inducing immunosuppression of the parasitized *P. xylostella*.

### 3. Transcriptional control by a viral gene, CpBV-H4

Histones are components of eukaryotic nucleosome and include H1, H2A, H2B, H3, and H4. DNA wraps core octamer consisting of each dimer of H2A, H2B, H3 and H4. H3 and H4 play crucial roles in nucleosome formation by covalent modifications, such as phosphorylation, methylation, and acetylation, at their protruding N-terminal tails. Modulation of nucleosomal formation changes DNA condensation and controls access of RNA polymerase. This epigenetic control is a main character of eukaryotic gene expression.

CpBV encodes a histone H4-like gene (called CpBV-H4), which shares high homologous sequence with histone H4 of *P. xylostella*, but possesses extra 38 amino acids in N-terminal tail with several lysine residues. We showed that transient expression of CpBV-H4 suppresses host gene expression. Pull-down experiment with a recombinant CpBV-H4 against nuclear extract of nonparasitized *P. xylostella* showed that CpBV-H4 can interact with some nucleosomal components. Subtractive suppression hybridization (SSH) was conducted to isolate target genes inhibited by the expression of CpBV-H4 and the resulting cDNAs were sequenced by 454 pyrosequencing technique. A total of 610 isotigs were identified and classified mainly into metabolism, signaling, and immune functions. Physical mapping of these genes on genome of *Tribolium castaneum* showed that target genes inhibited by CpBV-H4 are scattered on different chromosomes, suggesting its nonspecific action using its aberrant epigenetic control.

### 4. Translational control by a viral gene, CpBV15 $\beta$

Translational control is a well known mechanism of some viruses to manipulate host physiology. Translational control was reported in another type of PDV, *Campoletis sonorensis* ichnovirus, in which specific mRNAs of parasitized host insect are inhibited at post-transcriptional level. Two homologous genes named CpBV15 $\alpha$  and CpBV15 $\beta$  share sequence homologies with eukaryotic initiation factors. Especially, CpBV15 $\beta$  shares sequence homology with a specific eIF4A-interacting domain of eIF4G. It discriminates host mRNAs depending on secondary structure of 5' UTR. Target mRNAs have complicated 5' UTRs estimated to be high thermal stabilities. Chimerical mRNAs changed target mRNA to nontarget mRNA or nontarget mRNA to target mRNA against inhibitory action of CpBV15 $\beta$ . After transient expression of CpBV15 $\beta$ , total plasma proteins were separated by two dimensional electrophoresis and compared with control plasma. Specific

target and nontarget proteins were selected and identified by tandem mass spectroscopy and MALDI-TOF analysis. The identified genes supported the importance of 5' UTR structures to be inhibited by CpBV15 $\beta$ . Immunoprecipitation with CpBV15 $\beta$  against cell extract of nonparasitized *P. xylostella* coprecipitated eIF4A. These results clearly suggest that CpBV15 $\beta$  sequesters eIF4A to inhibit efficient translation of its target mRNAs, which are highly dependent on helicase activity of eIF4A.

### **5. Novel approaches using molecular targets**

This study identified several different molecular targets of host insects against two types of microbial pathogens. PLA<sub>2</sub> is a molecular target of *X. nematophila* and its inhibition leads to significant immunosuppression. We identified several PLA<sub>2</sub> inhibitors from the bacterial culture broth. These inhibitors alone can suppress insect immune responses. Addition of these PLA<sub>2</sub> inhibitors to current Bt pesticide significantly enhances the bacterial pathogenicity by suppressing host immune defense.

CpBV inhibits immune responses by disrupting immune-associated genes and alters larval development by altering transcription or translation. Direct suppression of these host gene expressions may confer similar physiological alterations. Current RNA interference technique using double stranded RNA (dsRNA) can be applicable to suppress the target host genes of CpBV. For example, oral administration of dsRNA of integrin caused significant mortality of *Spodoptera exigua*. The RNAi technique using various molecular target genes would be a promising pest control strategy by disrupting insect physiological processes.

### **Acknowledgement**

This study was supported by a basic science grant of National Research Foundation, an agenda grant of Rural Development Administration, second stage BK21 grant of Ministry of Education, Science, and Technology.

## Insect pest management in rice

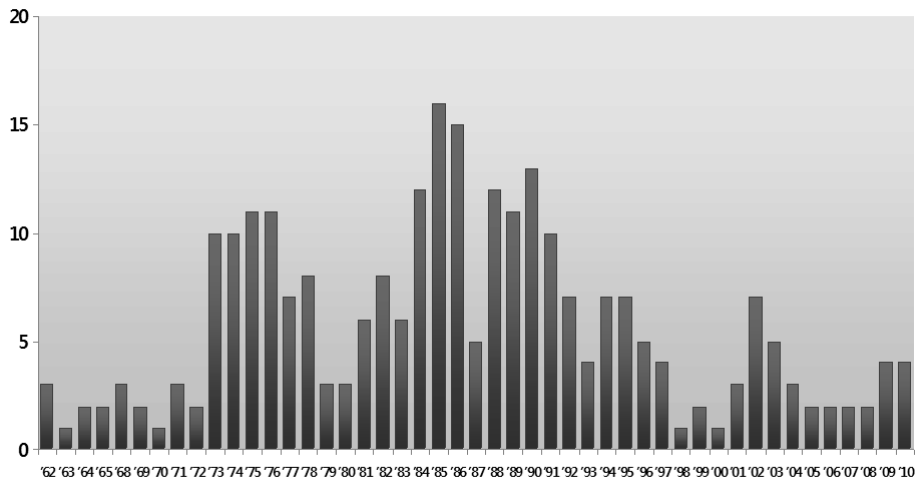
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### Research trends of rice pests from 1962 to 2010

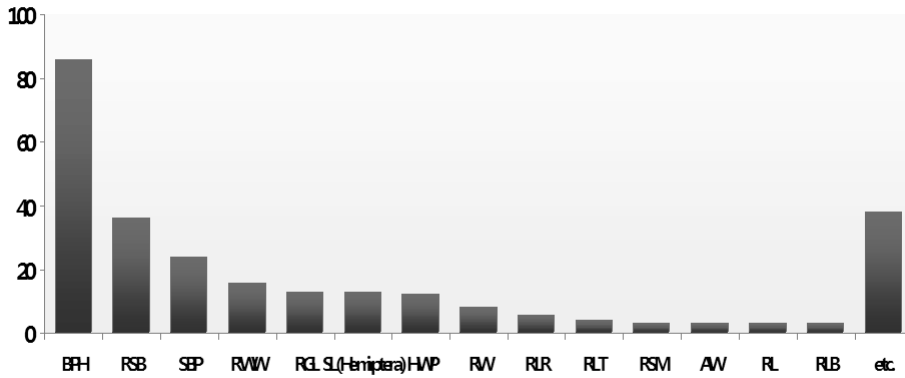
It was analyzed research trends related to rice pests from four journals (Korean Society of Applied Entomology, The Korean Society of Pesticide Science, RDA Journal of Agricultural Science, Journal of Asia-Pacific Entomology). The total papers of studied rice pests were 272 articles from 1962 to 2010. The Brown planthopper was the most 86 articles under the rice pests and the following striped rice borer 36 articles. The fields of study were insect ecology & behavior 49%, pest management 34%, taxonomy & morphology 1% and the others 16%. The rate of articles by insect orders was studied homoptera 57%, lepidoptera 19%, coleoptera 10%, hemiptera 5% and the others 9%.

### Yearly number of articles of rice pest



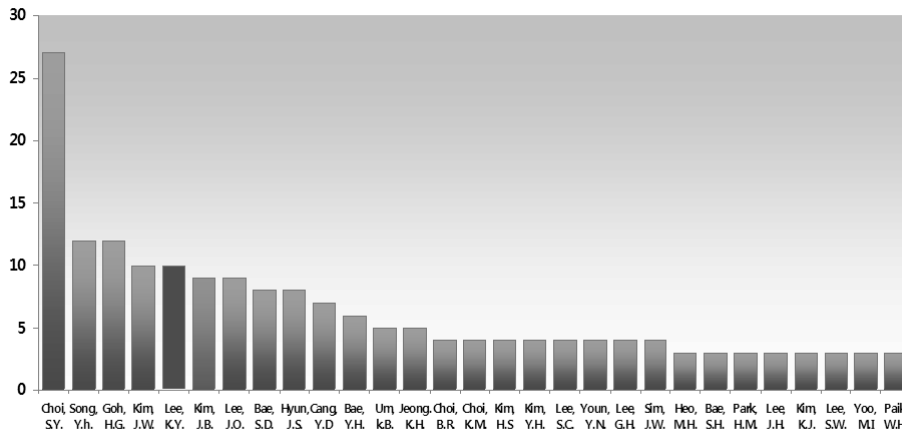
(Korean Society of Applied Entomology, The Korean Society of Pesticide Science, RDA Journal of Agricultural Science, Journal of Asia-Pacific Entomology)

### The number of papers by rice pests



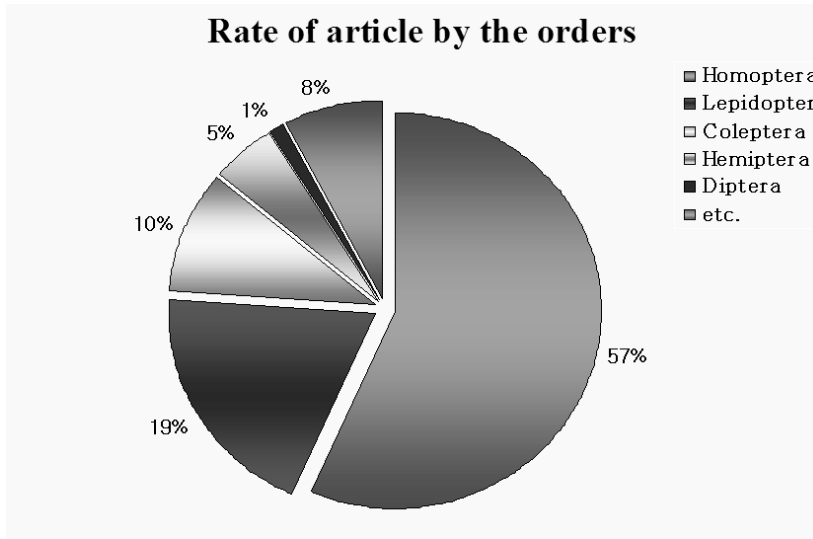
(Korean Society of Applied Entomology, The Korean Society of Pesticide Science, RDA Journal of Agricultural Science, Journal of Asia-Pacific Entomology)

### The number of articles by researchers

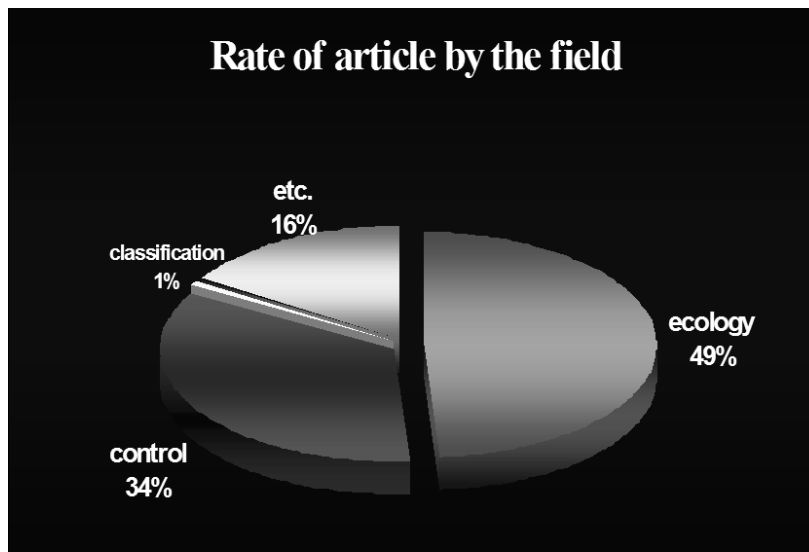


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(Korean Society of Applied Entomology, The Korean Society of Pesticide Science, RDA Journal of Agricultural Science, Journal of Asia-Pacific Entomology)

**Rice Water Weevil, *Lissorhoptus oryzophilus* (Coleoptera: Curculionidae)**

The peak of overwintered adults was late May and that of newly emerged adults was early August. Oviposition occurred in late May and late June and its peak was observed on early June. Larvae were observed from early June to early August and pupation occurred from early July to late August. The first adults of newly emerged rice water weevil was observed on early July and its emergence peak was early August. RWW prefers to overwinter under leaf litters, or in the soil mountain foot, banks, of ridges located where winds are blowing to. Most of those overwintering RWWs were found from leaf litters, and the soil up to 5cm deep. The calculated threshold temperature for development of flight muscles (epipleural muscle) was 14.9°C. The 50% immigration time of overwintered adult from overwintering sites to paddy fields can be estimated by knowing the date when the accumulative day-degree above 14.9°C reaches a value of 63.1 day-degrees. Diapausing adults showed significantly higher survival rates in response to -10°C than did reproductive adults. Mean supercooling points were not significantly different between diapausing and reproductive adults with a range between -15°C and -18°C. Glucose and trehalose were the major sugar polyols and showed the greatest change in autumn field populations. Reproductive populations kept high glucose contents during summer, while diapausing populations had high trehalose contents during winter. Cold-acclimated weevils also elevated trehalose contents. Most sugar alcohols, however, were relatively low except in May when the sorbitol content of the weevils increased significantly. These results indicate that the diapausing rice water weevil, a freeze-susceptible species, is cold-tolerant with elevated trehalose content. The overwintered adult began to feed on rice leaves from April 5, and the feeding peak period was between late May and early June. The feeding peak of newly emerged adults on rice was between late July and early August. The adults can migrate from paddy field to overwintering sites after feed on rice leaves of 0.9mm in width and 84.8-92.9 cm in length. The total numbers of eggs laid by overwintered adults collected on May 16 were 100.3 under the laboratory conditions. The eggs of rice water weevil were laid on the 1st and 2nd leaf sheaths in 1-3 cm water level from bottom. The calculated developmental threshold temperature was 16.26°C, and the total effective day-degree above 16.26°C take a constant value about 60.6 day-degrees. Egg periods were shortened as temperature increased, but the hatching rate was highest(100%) at 27°C. The developmental periods from egg to adult were shortened as temperature increased : from 77.9 days at 20°C to 38.3 days at 30°C. The developmental zero point temperature (T) and the total effect temperature (K) for egg were 16.3°C and 62.1 degree days, respectively. The T

and  $K$  from egg to adult emergence were  $13.9^{\circ}\text{C}$  and  $577.6$  degree days, respectively. The adult females of the first generation did not oviposit at  $20^{\circ}\text{C}$ , but did at  $25^{\circ}\text{C}$  and  $30^{\circ}\text{C}$ . The intrinsic rate of natural increase ( $r_m$ ) increased as temperature augmented. Net reproductive rate ( $Ro$ ) per generation was highest (75.3) at  $25^{\circ}\text{C}$ .

#### **Rice leaf beetle, *Oulema oryzae* (Coleoptera: Chrysomelidae)**

Effect of temperature on oviposition and developmental period of *Oulema oryzae* on rice plant were investigated. With the given set of temperatures of 15, 20, 23, 25, and  $28^{\circ}\text{C}$ , developmental period from egg to adult emergence was shorten as temperature increased. Average number of eggs per female *O. oryzae* increased as temperature increased from  $15^{\circ}\text{C}$  to  $23^{\circ}\text{C}$ , then decreased at  $25^{\circ}\text{C}$  and  $28^{\circ}\text{C}$ . Based on this result, developmental threshold temperatures for egg was estimated to be  $6.4^{\circ}\text{C}$ . Total effective temperatures above the thresholds required for hatching were estimated to be 75.8 degree-days for egg. It seemed that the optimum temperature for oviposition of *O.oryzae* on rice plant was  $23^{\circ}\text{C}$ .

#### **Rice Black Bug, *Scotinophara lurida* BÜRMEISTER (Hemiptera: Pentatomidae)**

Egg of *S. lurida* was oval-shaped with light-gray in color. Nymphs were reddish brown, dark brown, and brown, and the body was 1.19~7.24mm long, depending on their developmental stages from the 1st to the 5th instar. Adults were black and the body were 9.34mm and 8.47mm long in female and male, respectively. In laboratory condition( $25\pm 2^{\circ}\text{C}$ ), adult longevity was 27.2 days, and the female laid 30.7 eggs in average for its life span. Developmental period was 4.3 days for eggs, and 45.8 days for nymphs. Total 9 host plant species was identified by the greenhouse observation in Chungbuk province. Attraction by light trap from overwintering site of overwintering adults occurred from early June to mid July and its peak was shown on late June. Eggs were oviposited from early July to early August and its peak appeared in late July. Nymphs were observed from mid July to late September with its peak on mid August. The newly eclosed rice black bugs were found in late August and its peak on mid September. The rice black bug overwintered as adult at mountain foot, banks, and rice paddy levee.

#### **Rice Skipper, *Parnara guttata* Bremer et Grey (Lepidoptera: Hesperidae)**

Egg was hemisphere-shaped in pink. Larva was milky white of yellowish green color with 2.9-30.6 mm body length, depending on their developmental stages from 1st to 5th instar. Pupa were grayish brown from 23.8 to 25.7 mm

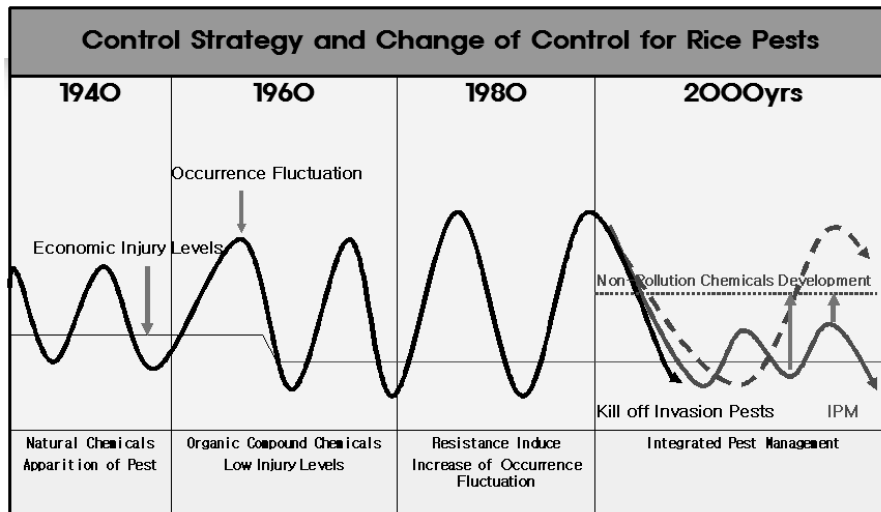
length, adults were yellowish brown color and body lengths were 17.4mm and 16.2mm and wing expanse lengths were 35.2mm and 30.6mm with female and male, respectively. At  $25\pm 2^{\circ}\text{C}$ , each developmental periods was 4.5, 30.2, and 6.9 days with egg, larvae, and pupae, respectively. Also adult longevity were 10.1 for female, average number of egg was 205.5.

Years rice pest grouping according to requirement of control

Years	Rice pests (13 species)		
	Major pest	Minor pests	Extinct pests
~1960	Small brown planthopper(+++) Brown planthopper(++) White-backed planthopper(++) Rice stem borer(++)	Rice leaf folder Rice green leafhopper Rice leaf beetle Rice Stem Maggot	
1970	Brown planthopper(++) White-backed planthopper(++) Rice leaf beetle Rice leaf folder Rice Stem Maggot	Rice stem borer Rice green leafhopper Small brown planthopper	
1980	Brown planthopper White-backed planthopper Rice leaf beetle Rice Stem Maggot	Rice stem borer Rice leaf folder Small brown planthopper Rice green leafhopper	
1990	Rice water weevil Brown planthopper White-backed planthopper Rice leaf folder	Rice stem borer Small brown planthopper Rice green leafhopper Rice leaf beetle Rice armyworm Rice green caterpillar	
2000~	Rice water weevil Rice black bug Small brown planthopper Brown planthopper Rice leaf folder Rice skipper Bugs	Rice stem borer Rice green leafhopper Rice armyworm Rice green caterpillar Rice Stem Maggot	Rice leaf beetle

### Integrated management of rice pests

Ecological IPM of major rice pests is crop rotation, damage evasion under control of rice transplanting, dry direct sowing and water management, selection of rice propagation house, remove host plant of pests and grow resistant variety. Pest management by natural enemies can use the spiders(*Pirata subpiraticus*; lycosid spider), predaceous insect(mantoda, hemiptera, dragonflies, rove beetles), parasitic natural enemy(*Gonia foersteri*; parasitoid) and entomopathogenic nematode. Pest management at organic rice growing is sound agriculture, protection and utilization of natural enemies, cyclic observation of rice paddy and application of economic injury level.



**Key words:** Rice, pest papers, Ecology, Control, IPM

## **Insect pest management of fruit tree orchards in Korea**

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Aspects of insect pest occurrence in fruit tree orchards have shown considerable fluctuation during the past decades in Korea. The fluctuations were largely affected by changes in cultivation systems, varieties, orchard management systems, pesticides, and climate changes in Korean peninsula. Insect pest control concepts have been changed from routine sprays for key insect pests in orchards by 1990's to schedules sprays based on IPM (integrated pest management) and IFP (integrated fruit Production) systems in 2000's. In this review, we summarized the major insect pest problems in fruit tree orchards and the insect management systems in Korea.

### **1. Insect management in apple**

Major insect pests in apple orchard in 1918-1945 were *Eriosoma lanigerum* (Hausmann), fruit moth (*Carposina sasakii* Walsingham, *Grapholita molesta* (Busck), *Spilota ocellana*, leaf roller, scales, *Agrilus mali* (Matsumura). The control methods for these insects were lead arsenate, pyrethroids, derris, machine oil, and cupping. The key pests in 1945-1960 were fruit moth (*Carposina sasakii* Walsingham, *Grapholita molesta* (Busck)), leaf roller, mite (*Panonychus ulmi* Koch, *Tetranychus urticae*), aphid, *Cryptotympana dubia* (Haupt), *Scintillatrix djingischani*. In this period, organophosphates such as DDT, Dichofol, Polydol, Matasystox were widely used, and resulted in outbreak of mites in apple orchards.

*Tetranychus urticae* was the dominant pest in most orchards until 1990's, but the population density is decreasing in orchards practicing low chemical control with sod culture. As the cultivation system changed, *Panonychus ulmi* became dominant in some orchards. By 1990's, *Carposina sasakii* Walsingham, was the one of the key pests in apple, however, the damages of *Grapholita molesta* (Busck) increased in 2000's.

IPM study in apple orchard began in 1980's. Sex pheromone for *Carposina sasakii* Walsingham was tested in early 1980's, and 6 kinds of pheromone traps were domestically commercialized. In late 1990's, mating disruption tests using sex pheromone were conducted to reduce chemicals in apple orchards, and the insecticide sprays decreased to 9 times (+2 times optional) in early 2000's.

Introduction of IPM (Integrated Pest Management), IFP (Integrated Fruit Production), and GAP (Good Agricultural Practice) systems in apple orchard management greatly contributed for reducing chemical sprays in apple orchards. An apple farmer's network, ([www.iloveapple.co.kr](http://www.iloveapple.co.kr)), established in 1995 and an apple information network, ([www.apple.go.kr](http://www.apple.go.kr), Integrated Fruit Information System), played very important roles in sharing pest management information among the apple farmers. Through the networks, farmers and researchers are exchanging information on insect and disease forecasting, pest occurrences, fruit tree growth stages, and production amounts.

## 2. Insect management in pear

A total of 306 insect species were recorded as pear orchard pests in Korea, and among them, 166 species belong to Lepidoptera. Major pests are *Grapholita molesta*, *Adoxophyes orana*, leaf mites, aphids, scales, and *Psylla pyricola*. *Grapholita molesta* occurs 4 times in Korea, and the pheromone developed in 1995 is widely used in pear orchards for forecasting purpose.

The dominant mite species in pear is *Tetranychus urticae*, and *T. kanzawai* and *Panonychus ulmi* are also the key pests. Until the late 1990's, farmers sprayed miticides 12-17 times, but the spray decreased to 2-3 times per year in the recent years affected by sod culture system.

## 3. Insect management in grape

In grape, about 100 species are reported as pests. There is some difference in key pest in grape according to the cultivation systems. Under open field condition, the key insect pests are grape tiger longhorn (*Xylotrechus pyrrhoderus*), green leaf bug (*Apolygus spinolae*), grape clearwing moth (*Nokona regalis*), and grape plum moth (*Nippoptilia vitis*), while two-spotted spider mite (*T. urticae*), thrips, scales, and, grape leafhopper (*Aroboridia apicalis*) and grape leafroller (*Herpetogramma luctuosalis*) are the major pests under structure.

Grape leaf louse (*Viteus vitifolii*) outbreak in major grape production area caused serious damages in late 1990's, but the problem was solved by utilization of resistant rootstocks and chemical control. Recently, outbreak of spot clothing wax cicada (*Lycorma delicatula*) became a top issue in grape pest management. A national eradication program for this insect operated from 2008 was very successful and the damage decreased to negligible level in 2010. A nationwide survey on the overwintering egg mass in April 2011 showed that the numbers were about 5-10% of the last year.

In Chungbook province, ussur brown katydid (*Paratlanticus ussuriensis*) outbreak was reported in 2007, but the population significantly decreased since the intensive control efforts after 2008. A clearwing moth, *Toleria romanovi*, is occurring in most grape production areas. *T. romanovi* can induce serious damage because the larvae excavates trunk of the grape tree. Damages of yellow tea mite, *Polyphagotarsonemus latus*, were recently found in several areas.

#### **4. Insect management in peach**

Major insect pests in peach production area are fruit moths (*Carposina sasakii* Walsingham and *Grapholita molesta* (Busck)). The occurrences of those pests mainly depend on weather conditions. *G. molesta* causes severe damage in early bud as well as in peach fruit. Recently, efficiency of mating disrupters for the control of those fruit moths has been carried out in some peach orchards.

#### **5. Insect management in citrus**

Major insect pests in Jeju citrus production area are as follows; mites (*Aculops pelekassi*, *Panonychus citri*), aphids (*Aphis citricola*, *Myzus persicae*, *Aphis gossypii*), scales (*Unaspis yanonensis*, *Pseudococcus cryptus*), thrips (*Scirtothrips dorsalis*, *Frankliniella occidentalis*), moths (*Phyllocnistis citrella*, *Ascotis selenaria*, *Homona magnanima*). Recent analysis on the effects of elevated temperatures on the population phenology and abundance of citrus pests in Jeju revealed very interesting results.

The population abundance of the selected citrus pests has largely been changed from 1970's to 2000's. Several pests such as *A. pelekassi*, *A. gossypii*, *P. cryptus*, *S. dorsalis* and *U yanonensis* have largely increased during the 1970's to 2000's, with showing an endemic outbreak in case of *S. dorsalis*, *P. cryptus*, and *A. pelekassi*, recently. Global warming in Jeju greatly affects EDPG (Effective



Duration for Population Growth) of citrus pests. The EDPG greatly increased more 24d to 38d in 2000's compared to that in 1960's. The thermal fitness of the selected citrus pests has increased over the last century. *A. pelekassi*, *A. gossypii*, *P. cryptus*, *S. dorsalis*, and *P. citrella* showed positive fractional changes in thermal fitness over whole seasons during the last century. Also, above species were expected to be increased in thermal fitness over whole seasons at temperature projected in the future.

## **Pest management of protected crops in Korea, future and present**

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The area of protected cultivation in the world since 1970s when it hardly seen at the area other than the temperate regions, increased constantly due to the development of inexpensive materials, and contributed to make possible mass production of vegetables during the winter with higher productivity than in open field. In Korea, it was 1979 when the area of protected cultivation began to increase.

In Korea, according to the statistics administration the area of protected cultivation was 4,966ha in 1979, about 0.17% of total cropping area, increased to 91,487ha in 2010, which accounts for about 4.8% of total cultivation area. Major crops growing in greenhouse includes cucumber (together with water melon and melon), pepper, and tomato, and strawberry, which accounts for 30.4% (27,813ha), 6.2% (5,704ha), 6.5% (5,951ha), and 6.7%(6,094ha), respectively.

### **1. Pests Occuring on Greenhouse Crops**

Major insect and mite pests of greenhouse crops include aphids, thrips, whiteflies, fungus gnats, mealybugs, spider mites, leafminers and scales. In cucumber 62 pest species, in pepper (including paprika) 64 pest species, in tomato 54 pest species, and in strawberry 52 species pest species of insect and mite are recorded in Korea. However, among the many pests only a few species are considered as key pest. In cucumber, cotton aphid (*Aphis gossypii*), greenhouse whitefly, Palm thrips (*Thrips palmi*), and cotton caterpillar (*Palpita indica*) are often cause damage. In pepper, oriental tobacco budworm (*Helicoverpa assulta*), garden thrips (*Frankliniella occidentalis*), green peach aphid (*Myzus persicae*), and cotton aphid (*Aphis gossypii*) are major pests. In tomato, green-

house whitefly (*Trialeurodes vaporariorum*), sweet potato whitefly (*Bemisia tabaci*), and america serpentine leaf miner (*Liriomyza trifolii*) are considered as key pests. And in strawberry, two-spotted spider mite (*Tetranychus urticae*), cotton aphid (*Aphis gossypii*), and Palm thrips (*Thrips palmi*) are often reach economic threshold level.

## **2. Tools for the control of Greenhouse Pests**

Since so called “친환경유기농자재 목록공시제”, the listing up service of environmentally friendly agro-materials for the materials which are allowed to use for the control of pests in organic culture in Korea was installed March, 2007, a total of 1,154 items were enlisted as of January 16th, 2011, among them are 263 items as pest management use including 127 items of natural enemy products. Most of the natural enemy products enlisted are multiple listed so that the species of the natural enemy involved are much less than the number enlisted, natural enemies currently commercially available in Korea is 31 species including 2 species of pathogenic nematodes and one banker plant.

Rural Development Administration (RDA) and Ministry of Agriculture Forestry and Fisheries (MAFF) made amendment on the enlisting service last year by introducing the quality certification regulation and made it possible to use certification label and allowed to print the usage of the item on the label. And the regulation about penalty as well as the inspection of the product was reinforced. Accordingly the products enlisted in the service are expected to be used by consumers with more confidence.

## **3. Research on the pests occurring in Greenhouse**

The research papers about greenhouse pests which have been published by January, 2011 were total 75, since 2001. It appeared that the subject on which the largest number of articles were published was biological control (18 articles), and followed by the articles about physiology of insect pests, those about chemical control and those about ecology. As was expected, in year 2008, when biological control was on the way to go due to the support provided by government for the farmers up to 50% of the money spent to purchase natural enemies, the largest number of articles was published in the field of biological control in Korea.

#### **4. Future direction of Research**

Since the effect of natural enemies in greenhouse for biological control is limited, the integrated use of natural enemies and other control measures is essential. Suitable crops for integrated control using natural enemies are those attacked by a small number of serious pests, those for which a low level of pest damage is tolerable, and those which require insect pollinators. Tomato and strawberry are both promising crops for integrated control in Korea.

As the Insect Industry Development and Support Act was enacted in 2010, the industry of natural enemy expected to be proliferated in Korea and as the support program of government for the farmers who buy natural enemies was discontinued. In the area of research, to help the natural enemy industry and biological control activity of growers realize the benefits of the act, development of relevant technology and methods for both the industry and biological control practice is required more than ever. Technology about mass production and quality control of the natural enemies in market and methods for effective way of using the natural enemies in the field in an effort to reduce the cost of biological control should be in a priority for the time being when it is concerned with biological control in protected cultivation.

## Insect pest management in forests

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Numerous insects live in forests as a component of forest ecosystem. Forest insect pests are defined certain insects when they adversely affect ecological, economic, and social values that we associate with forest. Kinds of forest insect pests are continually changed as a result of change of forest ecosystem and the introduction of foreign alien insect pests. Forest pest management is the maintenance of destructive insects at tolerable levels by the planned use of a variety of preventive, suppressive, or regulatory tactics and strategies that are ecologically and economically efficient and socially acceptable. However, the system of forest pest management is slightly different according to the nation and case of insect pests. Currently, the most important insect pests of Korea are *Monochamus* beetles and *Platypus koroensis*, which are insect vectors of pine wilt disease and oak wilt disease, respectively. Major forest insect pests are *Thecodiplosis japonensis*, a gall maker of pine needle and sapsucking insects such as black pine bast scale, *Matsucoccus thunbergianae*, *Corythucha ciliata*, *Lycorma delicatula*. Defoliating insects, such as *Dendrolimus spectabilis*, *Hyphantria cunea*, *Agelastica coerulea*, *Acantholyda parki*, and phloem boring insects, such as *Tomicus piniperda* and Ips bark beetles are also regarded as major forest insect pests. Management of forest insect pests are different from kinds of insect species. Control methods currently used are as follows; (a) Chemical control : ground and aerial spray of low-toxicity insecticide, trunk injection of systemic insecticide, fumigation, etc. (b) Biological control : release of parasitic wasps, use of *Beauveria bassiana*. etc. (c) Physical or mechanical control : burn, crush, etc. (d) Silvicultural practice : salvage cutting, clear cutting and reforestation, breeding of resistant trees, etc.

**Key words:** Forest insect pest, forest pest management, insect vectors, control

## **Management of medical insects**

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### **Background of vector control**

At the end of the nineteenth century, it was discovered that certain species of insects and other arthropods were responsible for the transmission of some important infectious diseases. Since effective vaccines or drugs were not always available for the prevention or treatment of these diseases, the prevention of transmission often had to rely mainly on the control of the vector. The discovery of the insecticide DDT in the 1940s was a major breakthrough in the control of vector-borne diseases. In the 1950s and 1960s, programmes were organized in many countries which attempted to control or eradicate the most important vector-borne diseases by the large-scale application of DDT. Initially these programmes were largely successful and in some countries it proved possible to interrupt or reduce the vector control activities. However, in most countries, success was short-lived; often the vectors developed resistance to the pesticides in use, creating a need for new, more expensive chemicals.

### **Alternatives to the use of insecticides**

Interest in alternatives to the use of insecticides has been revived because of increasing resistance to the commonly used insecticides among important vector species and because of concerns about the effects of insecticides on the environment. Environmental management involves altering the breeding sites of vectors, for instance by filling ponds and marshes on a permanent basis or by repeatedly removing vegetation from ponds and canals and cleaning premises. Biological control is the use of living organisms or their products to control vectors and pest insects. The organisms used include viruses, bacteria, protozoa, fungi, plants, parasitic worms, predatory mosquitoes and fish. The aim is generally to kill larvae without polluting the environment.

### **Selecting the appropriate control measures**

In selecting appropriate control measures, it is generally possible to distinguish two types of situation requiring different solutions: nuisance caused by pests or diseases carried by bloodsucking insects and other vectors. In both cases, solutions can be found in the protection of individuals and communities. It is important to distinguish between measures offering adequate protection from disease and ones that are not sufficient on their own but are of value in conjunction with other measures.

### **Management of medical insects of Korea Centers for Disease Control and Prevention**

As management measures for vector borne diseases, vector surveillance system and vector control system are created with management of infectious diseases such as malaria, Japanese encephalitis and scrub typhus.

- Surveillance for vector-borne disease

Malaria vector surveillance is conducted by collecting from 19 sites around malaria risk areas where the disease occurs. The seasonal population density of vector mosquitoes and infection rate of *Plasmodium* are conducted. Japanese encephalitis vector surveillance is the oldest vector surveillance system in Korea. It is currently being conducted at 39 sites nationwide, and it provides the precautionary attention at first appearance date and the alarm based on the number and rate of vector species. To monitor vectors that could be coming from overseas, various vectors (mosquitoes, cockroaches, rodents etc) are collected at the National Quarantine Station (17 sites) located at harbors and airports.

- National vector control and surveillance

To construct and strengthen standard laboratory system for disease vector control, supervision for renovating vector control methods under field condition, national monitoring on pesticide susceptibility and resistance of disease vector mosquitoes, issue of guideline and manual for vector control and management, national advisory committee for effective vector control were carried out. The education and manual provide background information that help workers to identify the vectors species, understand the vector ecology and apply the appropriate control measures. Practical information is given on a variety of control measures

- Construction of Vector-Net system

There is need to establish a comprehensive surveillance and management system (Vector-Net) on vector borne diseases that could efficiently respond to diseases from climate and environmental change by drawing up pest control strategies. This system is a united vector borne disease control that being connected vectors and patients surveillance, pathogen diagnosis, geographic information, regional customized eco-friendly vector control with infectious disease vector.



**검역 및 외래 해충 관리**  
**(Insect Pest Management and Quarantine)**  
**- 식물병해충 생물안전(Biosecurity) 및 위기관리**  
**(Emergency Management) 현황 및 전망 -**

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침입외래종(Invasive Alien Specie; IAS)이라는 용어는 비토착 생물체의 수와 분포가 환경적인 수용능력을 초월함으로써 사회복지에 부정적인 영향을 초래하는 경우에 적용될 수 있다. 기후변화로 인한 영향은 이전에 생각했던 것보다 더 빠르게 나타나고 있으며 이러한 경향은 더욱 지속될 것으로 여겨지고 있어 이에 대한 시급한 대응이 절실히 요구되고 있다. 특히, 국제교역은 IAS의 비의도적 또는 의도적 유입과 관련되어 가장 중요한 경로(pathway)가 되고 있으며, 농산품의 세계적인 교역 증가는 새로운 지역에서 해충화하는 IAS의 유입을 증가시킬 것이 확실시 되고 있어 우리나라의 생물안전(biosecurity) 시스템의 획기적인 개선이 요구되는 실정이다.

침입외래종 유입을 체계적으로 막기 위해서는 해외에서의 병해충 발생 실태조사, 현지검역(preclearance), 도착지 공·항만에서의 철저한 식물검역, 밀수품방지, 예찰을 통한 조기발견, 적절한 방제·박멸프로그램 및 병해충위험분석(Pest Risk Analysis)이 적절히 이루어져야 한다. 현재 국내의 식물병해충 생물안전 보장활동은 농림수산식품부 검역정책과, 국립식물검역원, 농촌진흥청 농업생물부, 산림청 산림과학원 등 각 기관이 일정한 역할 및 책임을 분담하고 있으나, 컨트롤타워 부재로 인해 체계적인 전략·정책 개발 및 효율적 이행에 어려움을 겪고 있다.

따라서, 한국의 식물검역 업무가 처음으로 시작되고(1959년), 한국응용곤충학회가 창립된 지 50여 년이 지난 현 시점에서, 한국의 식물병해충 생물안전 및 위기관리의 현주소를 미국 등 선진국의 사례를 토대로 예방(Prevention) 및 준비(Preparedness), 대응(Response), 복구(Recovery) 단계별로 비교 분석하고, 침입외래

해충의 유입을 효과적으로 차단하고, 조기발견 및 적기에 대응하기 위한 국내 제 분야간 협력적·상호적 생물안전 거버넌스(Biosecurity Governance) 구축을 위한 건설적인 방안을 모색하고자 한다.

**예방(Prevention)** 단계에서는 공·항만에서 실시하는 국경검역도 중요하지만, 국경 이전(pre-border)의 현지검역, 해외병해충 발생상황 조사는 물론 심지어 유입이 우려되는 검역병해충이 발생하고 있는 인접 국가 내에서의 방제·박멸 활동에 참여하는 것도 중요하고 요구되고 있다. 또한 국제식물보호위원회(IPPC) 및 아시아태평양지역식물보호위원회(APPPC) 등 국제적인 생물안전 보장활동에 참여하고 과학적인 병해충위험분석을 통한 수입제한 및 허가제도 운영 등도 요구되고 있다. 특히, 침입외래종을 조기에 검출할 수 있는 프로그램도 요구되고 있다. 미국의 경우에는 범정부적인 “농작물 병해충 예찰협력 프로그램(CAPS)”을 통해 실질적인 유입 우려가 높은 병해충을 지정하여 조기에 탐지해내는 시스템을 구축해 놓고 있는데, 예찰 대상 병해충 목록을 관련 학회(예: 미국곤충학회)에서 제공하는 등 민·관·학이 긴밀하게 공조하고 있다.

**준비(Preparedness)** 단계에서는 유사시를 대비한 범국가적인 대응시스템 마련이 요구되고 있다. 미국의 경우에는 식물검역적인 위험요소 및 돌발적인 병해충 발생을 조기에 탐지·진단하여 효과적으로 방제·박멸하고자, 정부기관 및 대학의 실험실을 연결한 “전국적인 병해충 분류동정·진단네트워크(NPDN)”를 구축하고 식물검역본부(Plant Protection and Quarantine; PPQ) 산하에 “국가분류동정원(National Identification Service; NIS)”을 설치하여 운영 중에 있다. 아울러, 유사시를 대비하여 새로운 병해충에 대한 대응 지침(매뉴얼)을 만들어 지속적으로 보완하고 있으며 “식물검역 재난통제시스템(Plant Health ICS)”을 구축하여 유사시에 필요한 조직, 시설·장비, 인력 및 의사소통 절차를 체계화·표준화하고 있으며, 평상시 교육훈련을 통해 식물검역 재난통제 전문가를 양성하고 있다.

**대응(Response)** 단계에서는 미국의 경우에 식물검역본부 산하의 “식물검역과 학기술센터(CPHST)”에 소속된 병해충위험분석 핵심 전문가들로 “새로운 병해충 자문그룹(NPAG)”를 구성하여, “국가분류동정원”으로부터 새로운 병해충이 확인되는 경우 신속한 평가를 통해 방제·박멸 조치 여부 등 적절한 대응방안을 제시하도록 하고 있다. 즉 긴급한 방제·박멸조치가 요구되는 경우에는 이미 마련된 식물

검역 재난통제시스템에 따라 조직적, 체계적으로 대응하고 있다.

**복구(Recovery)** 단계에서는 위기관리가 종료된 후, 해당 위험을 초래한 병해충으로부터 장기적으로 안정을 찾고 이들의 재유입을 방지하기 위한 시스템의 개선·개발을 필요로 한다.

이상의 사례로 볼 때, 우리나라 생물안전 시스템의 개선을 위해서는 지속적인 위험정보교환(Risk Communication)을 통한 인식의 공유와 정부 및 학계의 협력적 상호작용이 우선적으로 요구된다. 이와 관련하여 최근 점차 확대중인 위험정보 교환에 적극적으로 참여하여 건전한 비판과 전문적 식견을 교환할 수 있어야 할 것이다. 아울러, 정부차원에서는 침입외래종을 효율적으로 탐지·관리하기 위한 중앙관리시스템 구축을 위해 “국립 식물병해충 정밀진단 및 위험평가 센터”, “국가식물병해충 진단네트워크(원격진단 이용 포함)” 및 “국가식물병해충예찰방제단” 설치·운영이 시급히 필요한 실정이다. 특히, 국가식물병해충예찰방제단은 국가 공무원은 물론 민간 전문가들의 자발적인 참여로 구성되어, 평소 모의 훈련 및 지속적인 국내외 교육훈련을 통해 고도로 숙련된 전문가 집단으로 양성할 필요가 있다.





# 구두 발표

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## Disruption of cell-cell interaction by a polydnavirus gene, CpBV-ELP1

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A polydnavirus, *Cotesia plutellae* bracovirus (CpBV), is a symbiotic provirus to an endoparasitoid wasp, *C. plutellae*. When the wasp parasitizes its natural host, *Plutella xylostella*, larvae, CpBV viral particles are translocated to hemocoel of *P. xylostella* along with the wasp eggs. CpBV-ELP1 is encoded in a viral segment and expressed in the parasitized larvae during entire parasitization period. A recombinant baculovirus expressing CpBV-ELP1 was constructed and applied to a non-natural host, *Spodoptera exigua*, larvae. When the recombinant baculovirus was injected to hemocoel, CpBV-ELP1 was expressed in hemocytes as early as 2h postinjection and then later expressed in other tissues. When it was applied to diet, CpBV-ELP1 was expressed in midgut epithelium at 12 h and subsequently expressed in internal tissues. Both application methods of the recombinant baculovirus caused significantly higher mortality of *S. exigua* than non-recombinant baculovirus. Interestingly, midgut epithelial cells expressing CpBV-ELP1 by infection of the recombinant baculovirus showed poor cell-cell interactions. Integrin, a cell surface molecule associated with cell-cell interaction, was cloned in *S. exigua* and was confirmed in its expression in the midgut epithelium. A hypothesis was raised that CpBV-ELP1 interrupts integrin function by direct binding or by blocking internal integrin signaling.

**Key words:** Polydnavirus, CpBV, ELP1, Integrin, *Spodoptera exigua*

## Cross-talk between plasmatocyte spreading peptide and eicosanoid

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Insect blood cells (hemocytes) play a key role in defense against parasites and other pathogenic organisms that infect insects. Cellular immune responses exhibited by hemocytes are acute and effective to initially suppress pathogenic processes. Subsequently humoral immune responses executed by antimicrobial peptides completely cleared the pathogens with help of hemocytes. Two immune mediators, plasmatocyte-spreading peptide (PSP) and eicosanoid, are known to mediate cellular immune responses by activating hemocyte behavior. This study was focused on how these two immune mediators work together to express hemocyte spreading behavior. Both PSP and prostaglandins stimulate hemocyte spreading in dose-dependent manners in the beet armyworm, *Spodoptera exigua*. Interestingly, inhibition of eicosanoid biosynthesis inhibited PSP activity on mediating the hemocyte-spreading behavior. However, the addition of eicosanoid biosynthesis precursor, arachidonic acid, rescued the hemocytespreading activity. Inhibition of PSP or its receptor by each RNA interference are now under investigation to test whether PSP triggers eicosanoid signaling. These results suggest that there is a cross-talk between PSP and eicosanoid to express hemocyte-spreading behavior in response to bacterial challenge.

**Key words:** Plasmatocyte spreading peptide, Eicosanoid, Hemocytes, Arachidonic acid



## **HTIFs encoded in *Cotesia plutella* bracovirus discriminates mRNAs of arginine kinase and imaginal disc growth factor of *Plutella xylostella***

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An endoparasitoid wasp, *Cotesia plutellae* parasitized young larval of diamondback moth, *Plutella xylostella*. Parasitized larva exhibit significant immunosuppression and fail to metamorphose to pupal stage. Especially, during last instar of parasitized *P. xylostella*, massive nutrients divert from host to wasp development. HTIF (host translation inhibitory factor) encoded in *C. Plutella* bracovirus (CpBV) play a crucial role in suppressing host usage of amino acids. However, its inhibitory activity is selective by discriminating mRNAs based on their 5'UTR secondary structures. Our RT-PCR and proteomic analysis indicated that arginine kinase mRNA was inhibited by HTIF, but imaginal disc growth factor was not. Arginine kinase and IDGF were persistently expressed in parasitized *P. xylostella* with the gradual decrease at the late parasitisation period. Expression of arginine kinase and IDGF were also tissue specific in the gut/epidermis and haemocyte but not in fat bodies. Subsequent analysis of these gene functions by RNA interference explained the benefit of parasitoid for the mRNA discrimination by HTIF.

**Key words:** HTIF, *Cotesia plutellae*, bracovirus, *Plutella xylostella*, transcriptional control

## Overexpression of acetylcholinesterase compensates the reduced catalytic activity due to resistance-conferring mutations in the two-spotted spider mite

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Western blot analysis using acetylcholinesterase (AChE)-specific antibody was conducted to determine whether AChE gene (*Tuace*) duplication actually results in overproduction of AChE in *Tetranychus urticae* (TuAChE). The protein quantities of TuAChE in seven field-collected mite populations were precisely correlated with the copy numbers. To investigate the effects of each mutation on AChE insensitivity and possible fitness cost, eight variants of TuAChE were *in vitro* expressed using the baculovirus expression system. Kinetic analysis revealed that the Ala391Thr mutation did not change kinetic properties of AChE, whereas the Gly228Ser and Phe439Trp mutations significantly increased the insensitivity to monocrotophos. Moreover, when the Gly228Ser and Phe439Trp mutations are present together, insensitivity increased over a thousand-fold, showing that both mutations confer resistance in a synergistic manner. Presence of the mutations, however, reduced catalytic efficiency of AChE considerably, suggesting an apparent fitness cost in monocrotophos-resistant mites. Reconstitution of the multiple copies of AChE having different compositions of mutations revealed that the catalytic efficiencies of the six-copy and two-copy AChEs (resembling the AD and PyriF strains of mite, respectively) were still lower but comparable to that of wildtype AChE. These finding clearly suggested that multiple rounds of *Tuace* duplication was needed to compensate the reduced catalytic activity of AChE caused by mutations.

**Key words:** Gene duplication, Acetylcholinesterase, *Tetranychus urticae*, Baculovirus expression, Monocrotophos

## Neuromodulation of olfactory circuitry in the periphery of the American cockroach

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Olfaction as an important sensory modality in insects is essential for identification of hosts, mates, oviposition sites, and food resources in nature. In the cockroach, both olfactory sensitivity in the antennae and the formation of short- and long-term olfactory memories exhibit daily fluctuations that are regulated by the circadian system. An important problem is to characterize the signalling systems and molecules that are involved in this regulation of olfactory reception and olfactory behaviour. Recent results suggest that insect olfactory systems are modulated by both biogenic amines and neuropeptides. However, it remains elusive how these molecules modulate olfactory system in the peripheral systems. In the present study, our aim was to characterize the structure and organization of these signalling systems in the peripheral olfactory system of the American cockroach, *Periplaneta americana*. This work illuminated that tachykinin and its receptors regulate olfactory sensitivity in the antennae of the cockroach. Injections of tachykinin peptides caused decreases in the amplitude of the electroantennogram (EAG), cells that produce tachykinin were localized in the antennae, and olfactory receptor neurons expressed tachykinin receptors. Interestingly, the tachykinin expressing cells also express receptors for the biogenic amine, octopamine and injections of octopamine also cause reductions in EAG amplitude. These results suggest that both octopaminergic and tachykinin peptide signalling pathways are important regulators of olfactory reception in the cockroach. We propose the hypothesis that octopamine regulates the release of tachykinin from cells in the antennae that, in turn, modulate the sensitivity of olfactory receptor neurons.

**Key words:** American cockroach, Olfactory system, Octopamine, Tachykinin

## Comparative transcriptome analysis for the identification of genes putatively associated with imidacloprid resistance in the cotton aphid, *Aphis gossypii* (Hemiptera: Aphididae)

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The cotton aphid, *Aphis gossypii* (Glover), is one of the most serious pest in seed potato and various vegetable cultivation. The imidacloprid-resistant strain (IR) was over 200-fold more resistant to imidacloprid compared to a susceptible strain (S) as judged by LC<sub>50</sub> values. The IR showed cross resistances to other neonicotinoid insecticides. IEF and 2DE analyses revealed that general esterase isozyme patterns in IR were almost identical to those of S. Nevertheless, a significantly overexpressed protein spot was detected in IR. To identify differentially expressed genes in IR, comparative transcriptome analyses based on GS-FLX were conducted using total RNAs extracted from both IR and S strains, which generated ca. 290 Mb reads for each strain. Generally, most nicotinic acetylcholine receptor subunit genes, such as alpha 2 and beta 1, were more transcribed in S than in IR. In contrast, only alpha 5 subunit gene was 1.8 fold more expressed in IR. Seven ATP-binding cassette (ABC) transporter genes were newly identified in *A. gossypii*, among which only ABCC9 gene was highly expressed in IR. Therefore, this ABCC subfamily, a member of the MRP subfamily which is involved in multi-drug resistance, could be one of the main factors associated with imidacloprid resistance in *A. gossypii*.

**Key words:** *Aphis gossypii*, insecticide resistance, next generation sequencing, nicotinic acetylcholine receptor, ATP-binding cassette transporter

## **CpBV infection causes endocrine alteration of *Plutella xylostella* and inhibits pupal metamorphosis**

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Parasitization by *Cotesia plutellae* inhibits pupal metamorphosis of diamondback moth, *Plutella xylostella*. Two questions are raised : (1) which parasitic factor(s) is responsible for the antimetamorphosis and (2) how the parasitized larvae are altered in endocrine signals. This study addressed both questions. When *C. plutellae* bracovirus (CpBV), a parasitic factor of the wasp, alone was injected to nonparasitized *P. xylostella* larvae, it significantly inhibited pupal metamorphosis in a dose-dependent manner. Corpora allata (CA) and prothoracic gland (PTG) were compared in both nonparasitized and parasitized *P. xylostella*. In both groups, size and shape of CA were not different. However, PTG was detected on prothoracic tracheal trunk in nonparasitized larvae, but not detected in parasitized. CpBV injection to nonparasitized larvae inhibited the growth of PTG. Transcriptional factor, broad complex, was partially cloned and expressed in nonparasitized *P. xylostella*. In parasitized or CpBV-injected larvae, broad complex gene was not expressed during late larval stage.

**Key words:** Metamorphosis, parasitization, *Cotesia plutellae*, CpBV, *Plutella xylostella*

## **RNA interference of two ovary transcripts of an endoparasitoid wasp, *Cotesia plutellae*, suppresses replication of its symbiotic polydnavirus**

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Polydnaviruses (PDVs) are a group of insect double stranded DNA viruses and symbiotically associated with host endoparasitoid wasps. Their segmented genome is located in host chromosome(s) in a proviral form. Viral replication is initiated at the ovary during late pupal stages. Little is known about the factors involved in the viral replication. This study analyzed the ovarian transcripts of an endoparasitoid wasp, *Cotesia plutellae*, by 454 pyrosequencing and subsequent gene annotation. Out of 2,226 contigs and 12,457 singletons, 50 transcripts categorized in DNA replication, coat proteins, and viral origins were selected as putative viral replication factors. The selected genes were analyzed in their expressions according to host wasp development. Quantitative real-time RT-PCRs showed that some of the selected genes were expressed during the viral replication at late pupal stage. Using RNA interference, five putative genes were tested in their implication in the viral replication by analyzing viral DNA amplification, structure of ovarian calyx, and parasitism. RNA interference of contig#1004 (*broad complex*) or contig#174 (a viral *DNA polymerase* gene) significantly inhibited DNA amplification without any impairment of viral formation, and subsequently resulted in significant reduction in the wasp parasitism. This study reports that two wasp genes (or not encapsidated viral genes) are implicated in the viral DNA amplification and viral coat protein production during the polydnaviral replication.

**Key words:** Polydnavirus, *Cotesia plutellae*, Replication, Pyrosequencing, Transcriptome

## 블루베리에 피해를 주는 블루베리혹파리 (*Dasineura oxycoccana*) 발견 보고

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최근 신소득 과수로 블루베리를 재배하는 농가가 급증하고 있으며, 필요한 묘목을 공급하기 위하여 외국에서 다양한 품종의 블루베리가 수입되고 있다. 지금까지 블루베리는 국내에서 비교적 병해충이 적고 재배하기가 쉬우면서 과실을 팔아 높은 소득을 올릴 수 있어 인기있는 작목이 되었다.

최근 화성시 소재 블루베리재배지에서 잎이 흑변하면서 말리고 타들어가는 증상을 보이는 것이 원예특작과학원에 민원 의뢰되어 조사를 실시한 결과 미국과 캐나다에서 블루베리에 피해를 주는 해충인 블루베리혹파리 (가칭) (*Dasineura oxycoccana*)가 피해를 주는 것을 확인하였다. 이 종은 국내 기록되지 않은 북미원산의 해충으로 국내 블루베리재배지에서 처음으로 발견되어 보고하고자 한다. 유충은 블루베리 나무의 눈을 가해하여 생장점을 고사시키며, 꽃눈에 피해를 주면 과실이 열리지 않는 큰 피해를 줄 수 있다. 전국 조사를 실시한 결과 경북 상주, 전북 고창, 경기 평택 등에서도 해충의 발생을 확인하였으며, 묘목 수입 시에 번데기 상태로 유입된 것으로 추정되고 있다. 동정은 유충의 유전자 바코드를 분석하여 유럽 및 미국의 블루베리혹파리 유전 정보와 비교하였으며, 사육을 통해 수컷 성충을 확보하여 형태적으로도 일치하는 것을 확인하였다.

**검색어:** 블루베리혹파리, *Dasineura oxycoccana*, 혹파리과, 해충, *Vaccinium*

## Mass rearing of the box tree pyralid, *Glyphodes perspectalis*, with artificial diet and sex pheromone analysis

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In this study, we reared box tree pyralid, *Glyphodes perspectalis*, with artificial diet and identified sex pheromone. Insect F-II and leaf of box tree were used to make artificial diet. Box tree pyralid, *Glyphodes perspectalis*, is the most serious pest of box tree in Korea, and was recently introduced into Europe. The pheromone components of this moth have been identified as (Z)-11-hexadecenal (Z11-16:Ald), (E)-11-hexadecenal (E11-16:Ald), and (Z)-11-hexadecenol (Z-11-16:OH) in Japan. In this study, we identified pheromone components of this species by using GC and GC-MS. Three same components, such as (Z)-11-hexadecenal (Z11-16:Ald), (E)-11-hexadecenal (E11-16:Ald), and (Z)-11-hexadecenol (Z-11-16:OH) were also indentified in Korean population, but there was a little difference in ratios. The ratios of these three compounds of Japanese population and Korean population were 5:1.25:1, and 5:0.96:0.2, respectively. The ratios of Z and E-11-hexadecenal were similar, but the ratio of (Z)-11-hexadecenol was lower compared to Japanese population. In field bioassay, (Z)-11-hexadecenal or (E)-11-hexadecenal alone was not attractive to males, but the mixture of Z11-16:Ald and E11-16:Ald was attractive to males. The most effective ratios of Z11-16:Ald and E11-16:Ald was 5:1. Other ratios such as 1:1 and 1:5 (Z:E) was not attractive to males. The attractiveness of Z:11-16:OH will be tested in near future.

**Key words:** box tree, *Glyphodes perspectalis*, artificial diet, sex pheromone



## Phospholipase A<sub>2</sub> is activated Toll signaling in response to fungal infection

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An entomopathogenic fungus *Beauveria bassiana* (Bb), is a potent pathogen against the beet armyworm, *Spodoptera exigua*. Phospholipase A<sub>2</sub> (PLA<sub>2</sub>) activities were measured in both immune-associated tissues of hemocytes and fat body *S. exigua*. Upon the fungal PLA<sub>2</sub>s were significantly activated in both hemocytes and fat body. Considering inhibitory activity of BZA, we posed a hypothesis that BZA against PLA<sub>2</sub> activity of hemocyte, resulting in shutdown of eicosanoid biosynthesis, subsequently inducing immunosuppression, which leads to enhance Bb pathogenicity. This study directly analyzed the inhibitory activity of BZA on PLA<sub>2</sub> extracted from different immune-related tissues. At low micromolar range, BZA significantly inhibited PLA<sub>2</sub>s of hemocytes, fat body, and plasma, in which most PLA<sub>2</sub> activity was found in hemocytes. Interestingly, an immune signal receptor, *Se-Toll*, was related with PLA<sub>2</sub> activation. RNA interference (RNAi) of *Se-Toll* significantly inhibited PLA<sub>2</sub> activity while nonspecific RNAi did not inhibit the PLA<sub>2</sub> activity. The RNAi of *Se-Toll* also significantly suppressed hemocyte nodule response against Bb challenge. In addition, the fungal infection significantly induced activation of PLA<sub>2</sub> activity, which would lead to production of immune mediating eicosanoids. This study addressed the synergistic effect of BZA on Bb pathogenicity by its inhibition of PLA<sub>2</sub> activity, which was linked with Toll signal pathway.

**Key words:** phospholipase A<sub>2</sub>, eicosanoid, immune, *Spodoptera exigua*, *Beauveria bassiana*

## Cloning of a scavenger receptor gene from *Spodoptera exigua* hemocytes

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Scavenger receptors (SRs) are transmembrane cell surface molecules recognized in apophotic cells, bacteria and lipopolysaccharide. With no physiological information on SRs in insects except SR-CI of *Drosophila melanogaster*, a putative SR gene was cloned and characterized in *Spodoptera exigua*. A partial *S. exigua* SR gene was obtained from hemocyte transcripts and exhibited high homology with type C. Its expression was confirmed in all developmental stages. Among different tissues, *S. exigua* SR was expressed highly in hemocytes. To confirm change in SR expression by infection, *Escherichia coli* was injected to fifth instar and RNA was extracted after 10 hours. SR expression in hemocytes of *E. coli* injected larva was not significantly different from the control but SR expression in fat body of *E. coli* injected larva was higher than the control. It is expected that SRs of *S. exigua* are related with immune responses against bacteria such as *E. coli*. To address its function, *S. exigua* SR expression was suppressed by double-stranded RNA (dsRNA).

**Key words:** Scavenger receptors, cloning, immune, *Spodoptera exigua*

## **Pathogenicity of *Xenorhabdus* sp. isolated from *Steinernema monticolum* and its Bt synergistic effect**

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An entomopathogenic bacterium, *Xenorhabdus* sp., symbiotic to *Steinernema monticolum* was investigated in its insecticidal activity. The bacteria induced septicemia of two lepidopteran insects (*Plutella xylostella*, *Spodoptera exigua*), a coleopteran insect (*Tribolium castaneum*), and a hemipteran insect (*Riptortus clavatus*) when they were injected into hemocoel. The bacterial culture broth contained immunosuppressive factor(s) that inhibited hemocyte nodulation in response to heat-killed bacteria. The immunosuppressive activity appeared to be caused by inhibition of two main immune-associated enzymes, phospholipase A<sub>2</sub> (PLA<sub>2</sub>) and phenoloxidase (PO). HPLC analysis of the bacterial culture broth contained several PLA<sub>2</sub> inhibitors. The bacterial culture broth significantly enhanced Bt pathogenicity. These results support a novel insect pest control strategy using eicosanoid-biosynthesis inhibitors.

**Key words:** *Xenorhabdus* sp., *Plutella xylostella*, *Spodoptera exigua*, *Tribolium castaneum*, *Riptortus clavatus*, Bt, PLA<sub>2</sub>, PO, HPLC

## CATTS 소독 처리에 따른 사과 품질 조사

손예림, 김용균

안동대학교 생명자원과학과

환경조절열처리는 일명 CATTS (controlled atmosphere temperature treatment system)로 특정 해충의 생존 한계에 해당하는 고온을 처리하면서 방역효과를 극대화하는 기술로써 수확 후 소독 처리 기술인 메틸브로마이드 훈증처리를 대체할 친환경 수확 후 소독 기술로 개발되고 있다. 복숭아심식나방(*Carposina sasakii*)은 수출국의 검역 대상 해충이다. 본 연구는 국내 사과를 일부 외국으로 수출할 경우 검역대상으로 지목받고 있는 복숭아심식나방에 CATTS 기술을 적용하였고, 이에 따른 수출용 후지 사과의 품질을 조사하였다. 소독 처리에 사용된 CATTS는 시간당 16℃씩 증가하여 기기의 내부 온도가 46℃가 되었을 때 이산화탄소 15%, 산소 1% 환경 조건을 맞추어 주었고, 과실 내부의 온도가 44℃에 도달하였을 때 소독 처리를 시작하였다. CATTS 소독 처리는 0 분, 30 분, 60 분, 75 분, 90 분, 120 분, 150 분과 180 분으로 나누어 처리하였다. CATTS 소독 처리 후 후지 사과는 상온(25℃) 조건에서 1 일, 7 일과 14 일 저장하였고, 저온(1℃) 조건에서 1 일, 7 일, 14 일, 30 일, 60 일, 75 일, 90 일과 120 일 저장하였다. 저장 시기별로 사과 품질을 조사하였다. 사과 품질은 이화학 품질 특성(경도, 당도와 산도), 호흡 속도(에틸렌, 이산화탄소)와 외부·내부 갈변율을 조사하였다. 이화학 품질 특성과 호흡 속도에 따른 차이가 없었으며, 60 분 처리 시간을 기준으로 처리 시간과 저장 기간이 증가에 비례하였다.

**검색어:** CATTS, 복숭아심식나방, 이화학 품질 특성, 외부·내부 갈변, ‘후지’ 사과, 호흡 속도

## Identification and Field Evaluation of the Sex Pheromone of *Synanthedon bicingulata* (Staudinger)

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The sex pheromone of *Synanthedon bicingulata* (Staudinger), a major pest of peach trees in many regions of northeast Asia, was identified. Two major components from the pheromone gland extracts of female moths are *E3,Z13-18:OAc* and *Z3,Z13-18:OAc*, and the average ratio of these components is about 4:6, respectively. In addition to the major components, four minor components, *Z13-18:OAc*, *E2,Z13-18:OAc*, *E3,Z13-18:OH*, and *Z3,Z13-18:OH* also were identified from pheromone gland extracts. Field tests showed that *E3,Z13-18:OAc* and *Z3,Z13-18:OAc* are essential for attraction of male *S. bicingulata* moths, and males are optimally attracted to the blend ratio found in pheromone gland extracts of conspecific females. Addition of the minor glandular components (*Z13-18:OAc*, *E2,Z13-18:OAc*, *E3,Z13-18:OH*, and *Z3,Z13-18:OH*) did not affect captures of males to the primary binary blend. Thus, the blend of *E3,Z13-18:OAc* and *Z3,Z13-18:OAc* at the natural ratio can be used for monitoring populations of this species.

**Key words:** *Synanthedon bicingulata*, *E3,Z13-18:OAc*, *Z3,Z13-18:OAc*, Lepidoptera, Sesiidae

## Diagnostic Molecular Markers Against Internal Apple Feeding Insects

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Three insect pests internally feed pome fruits in Korea. These include oriental fruit moth (*Grapholita molesta*), plum fruit moth (*Grapholita dimorpha*) and peach fruit moth (*Carposina sasakii*). Molecular markers discriminating these three species were developed using PCR-RFLP technique. Mitochondrial (mt) genomes were analyzed to locate polymorphic loci. Six mtDNA regions (CO- I , CO- II , CB, 16SrRNA-12SrRNA, ND3, ND4) of *G. dimorpha* were cloned and sequenced. These six sequences of *G. dimorpha* were aligned with those of *C. sasakii* and *G. molesta* to determine polymorphic restriction sites. Predicted PCR-RFLP markers were confirmed with known insect samples. With the validated PCR-RFLP markers, field male adults collected in traps baited with rubber sept lures impregnated with different ratios of major sex pheromone components of *G. molesta* were analyzed.

**Key words:** *Grapholita molesta*, *Grapholita dimorpha*, *Carposina sasakii*, PCR-RFLP, Diagnosis

## Differential proteomes analysis from Chinese cabbage attacked by *Myzus persicae* and *Plutella xylostella*

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In this study, we compared global proteome profiles and the expression pattern of defense-related genes in Chinese cabbage when infested by *Myzus persicae* and *Plutella xylostella*. Four-week-old Chinese cabbage was exposed to each insect for 24 h, and then proteins and total RNA were extracted from leaves. To elucidate the herbivore-induced differentially expressed proteins in Chinese cabbage, proteins were separated by two-dimensional gel electrophoresis, and visualized by staining with Coomassie G250. Approximately 1600 protein spots were separated and 249 protein spots showed reproducible changes in expression. Among them, nine proteins whose expressions were markedly up-regulated in *M. persicae*-infested group were identified using matrix-assisted laser desorption/ionization time of flight mass spectrometry. The identified herbivore-responsive proteins (ribulose-1,5-bisphosphate carboxylase/oxygenase, ATP synthase CF1, putative mismatch binding protein Mus3, and integrase core domain-containing protein) were involved in regulation of photosynthesis, carbohydrate metabolism and DNA repair. The expression levels of chitinase, b-1,3-glucanase, peroxidase, PR1, and PR4 in herbivore-infested Chinese cabbage were analyzed by reverse transcription-polymerase chain reaction. The results clarify the response of Chinese cabbage to two herbivore attack at the protein level.

**Key words:** chinese cabbage, *Myzus persicae*, *Plutella xylostella*, 2-DE, defense gene

## Larvicidal Activity of *Cnidium monnieri* Seed Constituents and Four Structurally Related Compounds to Insecticide-Susceptible and -Resistant *Culex pipiens pallens*

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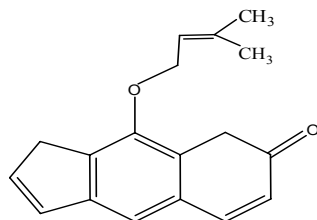
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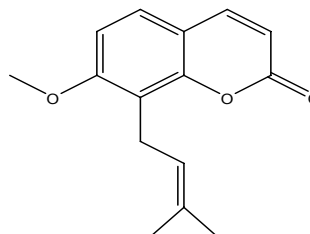
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The toxicity of imperatorin (**1**) and osthol (**2**) identified in *Cnidium monnieri* seed and four structurally related compounds to third instar larvae of insecticide-susceptible (KS-CP strain) and field-collected (DJ-CP colony) of *Culex pipiens pallens* was examined. Results were compared with those of conventional mosquito larvicide, fenitrothion and temephos. Based on 24-h LC<sub>50</sub> values, imperatorin was 1.9, 3.7, 4.2, 12.4, and 15.1 times more toxic than isopimpinellin, isoimperatorin, osthole, xanthotoxin, and bergapten against KS-CP larvae, respectively. Overall, these compounds were less toxic than either fenitrothion or temephos. However, these compounds did not differ in toxicity against larvae from the two *Culex* strains, even though the DJ-CP larvae exhibited high levels of resistance  $\alpha$ -cypermethrin, deltamethrin, chlorpyrifos, fenthion, and chlorfenapyr (resistance ratio, 94-1179). This finding indicates that the isolated compounds and the pyrethroid, organophosphorus, and pyrrole insecticides do not share a common mode of action or elicit cross-resistance.



(1)



(2)

**Key words:** Botanical mosquitocide, natural mosquito larvicide, *Cnidium monnieri*, imperatorin, osthol, insecticide resistance



## Screening and Selection of Acaropathogenic Fungi Against *Rhizoglyphus echinopus* (Acari: Acaridae)

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Won-Woo Lee<sup>1</sup>, and Soo-Dong Woo<sup>1</sup>

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The bulb mite (*Rhizoglyphus echinopus*) is damage garlic, shallot, onion in the bulbs, corms, tubers. It has recently become a serious problem because of the continuous use of acaricides resulting in resistance among bulb mite population. Thus, there is need to find alternative control measures to suppress bulb mite population. Initial screenings were performed using 352 isolates of pathogenic fungi from Korea soils. As results, 9 strains of acaropathogenic fungi were cadavers of bulb mite supporting fungal conidiation. These isolated were identified as 8 strains of *Metarhizium anisopliae* (4-1, 4-3-1, 4-3-2, 4-8-1, 4-4-1, 4-14-2, 4-16-1, and 4-31-2), 2 strains of *Beauveria bassiana* (4-4-2) by microscopic examination and genetic sequencing of the ITS region. However, ITS sequence analysis was consistent with the *Metarhizium anisopliae* (4-1, 4-3-1, 4-4-1, 4-31-2; a, 4-8-1, 4-14-2, 4-16-1; b, 4-3-2; c). Therefore, genetic diversity of selected in vitro isolates was characterized by Universally Primed (UP) PCR. The divided with *Metarhizium anisopliae* 4strain by UP-PCR. Of the 5stain isolation tested, 5stain resulted in mortality rates  $\geq 20\%$  within 6 days and all fungal treatment was detected mycosis. Thus these species of acaropathogenic fungi can be considered promising for biological control of bulb mite.

**Key words:** *Rhizoglyphus echinopus*, acaropathogenic fungi, UP-PCR

## **Efficacy Test of Clothianidin Granule against Green Peach Aphid(*Myzus persicae*) and Sweet-potato Whitefly(*Bemisia tabaci*)**

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The green peach aphid(*Myzus persicae*) and sweet-potato whitefly(*Bemisia tabaci*) biotype Q are serious pests in hot pepper and cucumber. To optimize the formulation type of Clothianidin 1.8% granule, coated and extruded granule formulation types were tested against green peach aphid in hot pepper and sweet-potato whitefly in cucumber. Clothianidin 1.8% granules were incorporated in soil before transplant of hot pepper and cucumber. At recommend dose(540g ai/ha), the efficacy of Clothianidin 1.8% coated and extruded granules were 83.3% and 94.4% and continued until 50 days and 70 days against green peach aphid, respectively. Against sweet-potato whitefly, the efficacy of Clothianidin 1.8% coated and extruded granules were 65.7% and 96.3% at 32 days in cucumber, respectively. Clothianidin 1.8% extruded granule was safe on crops (hot pepper, cucumber, melon, cabbage etc.) at 540g ai/ha (recommend dose) and 1080g ai/ha. The results suggested that Clothianidin 1.8% extruded granule is promising as a best insecticide against green peach aphid and sweet-potato whitefly, because of the high efficacy and low phytotoxicity.

**Key words:** Insecticide, Clothianidin, Green peach aphid, Sweet-potato whitefly, Granule

## **Electron beam irradiation induces abnormal development and the stabilization of p53 protein of American serpentine leafminer, *Liriomyza trifolii* (Burgess)**

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Department of Plant Medicine, Chungbuk National University

The American serpentine leafminer fly, *Liriomyza trifolii* (Burgess), is one of the most destructive polyphagous pests world wide. In this study, we determined electron beam doses for inhibition of normal development of the *L. trifolii* and investigated the effect of electron beam irradiation on DNA damage and p53 stability. Eggs, larvae, pupae and adults were irradiated with increasing doses of electron beam irradiation (six levels ranges from 30 to 200 Gy). At 150 Gy, the number of adults that developed from irradiated eggs, larvae and pupae was lower than those of untreated control. Fecundity and egg hatchability decreased depending on the doses applied. Reciprocal crosses between irradiated and unirradiated flies demonstrated that males were more radiotolerant than females. Adult longevity was not affected in all stages. The levels of DNA damage in *L. trifolii* adults were evaluated using the alkaline comet assay. Our results indicate that electron beam irradiation increased levels of DNA damage in a dose-dependent manner. Moreover, low doses of electron beam irradiation led to the rapid appearance of p53 protein with in 6 h; however, it decreased after exposure to high doses (150 Gy and 200 Gy). These results suggest that electron beam irradiation induced not only abnormal development and reproduction but also p53 stability caused by DNA damage in *L. trifolii*. We conclude that a minimum dose of 150 Gy should be sufficient for sterilization of *L. trifolii*.

**Key words:** electron beam, *Liriomyza trifolii*, sterility, DNA damage, p53

## Attractive distance of two different sizes of yellow sticky traps for greenhouse whitefly using variogram analysis

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Variogram analysis was used to estimate and compare the attractive distances of two different sizes of yellow sticky traps (small trap: 9.6×8.0cm; large trap: 9.6×16cm) for sampling greenhouse whitefly (GHWF), *Trialeurodes vaporariorum* (Westwood), adults in four commercial cherry tomato greenhouses. The patch size of GHWF immatures between plants was also estimated using visual counts. Two variogram models were fitted to the empirical variograms developed from the data collected by each sampling method. All the variograms reached the sill indicating the presence of spatial dependence among the spatial data obtained by the two sampling methods. For GHWF adults on sticky traps the range of variogram (a measure of attractive distance) was not different between the two trap sizes. This result indicated that the attractive distances of the two different yellow sticky traps were very similar. The ranges of the variograms for the visual count of immatures on plants were always less than those for adults, indicating that the attractive distance of the traps for GHWF adults extends beyond the patch size for immatures on cherry tomato plants. These data have implications for developing sampling plans for the management of GHWF in tomato greenhouses.

**Key words:** range, spatial autocorrelation, *Trialeurodes vaporariorum*, variogram, yellow sticky trap, visual count

## Selection of Acaropathogenic Fungi to Control Two-spotted Spider Mite, *Tetranychus urticae*

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Sung Min Bae<sup>1</sup>, and Soo Dong Woo<sup>1</sup>**

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The two-spotted spider mite, *Tetranychus urticae* Koch, is an economically important pest of crops of plant grown in the field or greenhouse worldwide. It has recently become a serious problem because of the continuous use of acaricides resulting in resistance among spider mite population. Thus, there is a need to find alternative control measures to suppress spider mite populations. In this study, we report the screening result of pathogenic fungi for the control of spider mite. Initial screenings were performed using 352 isolates of putative pathogenic fungi from Korea soils. As results, 11 strains of acaropathogenic fungi were isolated from 8 cadavers of spider mite supporting fungal conidiation. These isolated were identified as four isolates of *Beauveria bassiana* (6, 2R-3-3-1, 2R-4-5, 2R-4-7), two isolates of *Metarhizium anisopliae* (4-2, 2-2), one isolate of *Clonostachys rosea* 5-2, one isolate of *Lecanicillium attenuatum* 4-1, one isolate of *Pochonia suchlasporia* 2R-3-1, one isolate of *Aspergillus flavus* 7 and one isolate of *Isaria lilacinus* 2R-4-6 by microscopic examination and genetic sequencing of the ITS region. Based on the screening results, eleven isolates were tested for their virulence against adult spider mites. All fungal isolates were pathogenic to spider mite but mortality varied with isolates. These acaropathogenic fungi may be useful to develop eco-friendly acaricide to control two-spotted spider mite.

**Key words:** two-spotted spider mite, acaropathogenic fungi, biocontrol

## 월동형 점박이응애에 대한 Ethyl formate와 Eco2fume®의 혼증효과

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Methyl bromide (MB)는 대상범위가 넓고 속효성을 가지고 있어 세계적으로 널리 사용되어 왔으나 오존층 파괴물질로 등록이 되어 대체 혼증제 개발이 시급한 상황이다. MB 대체 혼증제로 ethyl formate와 Eco2fume (PH<sub>3</sub> 2% + CO<sub>2</sub> 98%, PH<sub>3</sub>)의 월동형 점박이응애에 대한 살충효과와 단감에 대한 약해를 조사하였다. 월동형 점박이응애는 경남 거창군의 사과 과수원에서 채집하였다. 혼증농도는 EF는 5.8~34.2 mg/L, PH<sub>3</sub>는 0.1~1.5 mg/L이었으며 혼증시간은 EF는 6 시간, PH<sub>3</sub>는 24 시간으로 두 약제 모두 5±1 °C에서 처리하였다. EF의 경우 LD<sub>50</sub>과 LD<sub>99</sub>값은 각각 66.3, 148 mg h/L 이었다. PH<sub>3</sub> 경우 LD<sub>50</sub>과 LD<sub>99</sub>값은 각각 6.5, 57.8 mg h/L이었다. 100% 사충률을 얻기 위해서 EF는 148 mg h/L 이상, PH<sub>3</sub>는 57.8 mg h/L 이상의 CT값이 필요하였다. EF와 PH<sub>3</sub> 혼증으로 인한 단감의 약해(경도, 당도, 부패율 등)는 없었다.

**검색어:** 점박이응애, 월동형, Vapormate, Eco2fume, 혼증

## EAG와 2차원 궤적 추적을 이용한 아메리카잎굴파리 (*Liriomyza trifolii*) 소리에 대한 반응 연구

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국립농업과학원 작물보호과

파리목 곤충의 청각기관은 더듬이의 존스톤 기관으로 알려져 있어, 소리에 대한 아메리카잎굴파리 더듬이의 반응을 EAG를 이용하여 조사하였다. 순음(사인파)과 아메리카잎굴파리 및 다른 3종의 구애노래를 절제된 아메리카잎굴파리 머리에 노출시키고 EAG를 통하여 반응을 관찰하였다. 순음의 경우 20 Hz의 저주파에서만 EAG 반응이 관찰되었다. 구애노래의 경우 검정발노랑굴파리(*Cryptonevra inquinata*)와 일본의 *Lipara japonica* 구애노래에 대한 반응이 나타났으나 아메리카잎굴파리 수컷의 구애노래에 대한 암컷의 EAG 반응은 나타나지 않았다. 조사된 음파에 대한 반응행동을 관찰하기 위해 2차원 궤적 추적을 추가적으로 실행하였다. 기록된 궤적은  $x$ 축 궤적의 평균값을 비교하여 소리에 대한 유인효과를 조사하였고, 궤적의 정보 엔트로피를 이용하여 활동성 차이를 분석하였다.  $x$ 축 평균값은 소리에 대한 차이가 없어, 소리에 대한 아메리카잎굴파리의 유인효과는 관찰하지 못하였다. 처녀 수컷과 암컷, 교미한 수컷에서는 소리를 노출시켰을 때 정보 엔트로피 값이 감소하여 활동성이 차이가 남을 알 수 있었으나 교미한 암컷에서는 활동성의 차이가 없었다.

**검색어:** 아메리카잎굴파리, 구애노래, 저주파, EAG, 반응 행동

## Allergen-Denaturing Activity of Propolis-Derived Compounds against *Dermatophagoides farinae* (Acari: Pyroglyphidae)

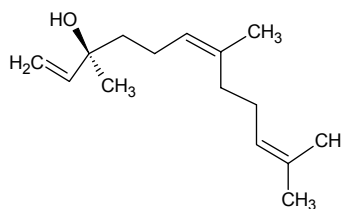
**Kym Na Ra Hwang<sup>1</sup>, Jun-Ran Kim<sup>2</sup>, Perumalsamy Haribalan<sup>2</sup>, Soon-Ok Woo<sup>3</sup>, Kwang-Gil Lee<sup>3</sup>, and Young-Joon Ahn<sup>2</sup>**

<sup>1</sup>Interdisciplinary Program in Agriculture Biotechnology Major, Seoul National University

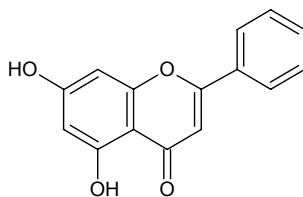
<sup>2</sup>WCU Biomodulation Major, Department of Agricultural Biotechnology, Seoul National University

<sup>3</sup>National Academy of Agricultural Science, Rural Development Administration

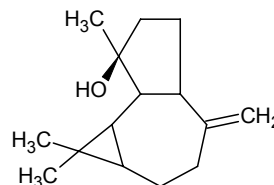
The American house dust mite, *Dermatophagoides farinae* Hughes, is the most important factor of allergic diseases, such as atopic dermatitis, rhinitis, and asthma. The protein-denaturing activity of nerolidol (**1**), chrysin (**2**), and spathulenol (**3**) identified in the Brazilian propolis against *D. farinae* was evaluated using SDS-PAGE and dot-blot immunoassay. Results were compared with those of the currently available dust mite protein-denaturing agent tannic acid. SDS-PAGE showed that application of test compounds and tannic acid (100 µg each) caused complete disappearance of *D. farinae* protein bands. In a dot-blot immunoassay, test compounds and tannic acid (100 µg each) strongly inhibited the IgE-binding reactivity to *D. farinae* protein of a highly mite-sensitive asthmatic patient. The Brazilian propolis constituents described merit further study as potential dust mite-allergen denaturants for protection from humans from various diseases caused by house dust mites.



(1)



(2)



(3)

**Key words:** *Dermatophagoides farinae*, propolis, nerolidol, chrysin, spathulenol



## Biochemical characterization of a novel pectate lyase3 in *Bursaphelenchus xylophilus*

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*Bursaphelenchus xylophilus* is known to be a major pathogen of the pine wilt disease (PWD). The pathogenicity of PWD is considered to be related to cell wall-degrading enzymes such as endoglucanases, expansins and pectate lyases (PELs). Two PELs, Bx-PEL1 and Bx-PEL2 are known to be expressed in *B. xylophilus* and regarded as a putative pathogenic factor. Recently, we developed stage-specific expressed tag library of *B. xylophilus* and identified a novel Bx-PEL3. We cloned Bx-PEL3 gene with RT-PCR, which showed high similarity to previously reported Bx-PELs. Phylogenetic analysis revealed that PEL3 was much closer to Bx-PELs than any other PELs. PEL3 has a conserved intron site as found in other Bx-PELs in the genomic DNA. Quantitative real-time PCR analysis revealed that Bx-PEL1 and Bx-PEL2 were more predominant in *B. xylophilus* than the Bx-PEL3. Recombinant Bx-PEL3 showed the activity for polygalacturonic acid and its physical conditions such as PH and Ca<sup>2+</sup> concentration for optimized activity were 9.0 and 0.5 mM, respectively. The localization of PEL3 transcript is the anterior body of *B. xylophilus*, near the esophageal gland. Taken together, these results suggest that a novel PEL3 gene is biochemically functional and can play a role as a putative pathogenic factor like other PELs.

**Key words:** *Bursaphelenchus xylophilus*, pectate lyase3, pine wilt disease, fluorescence *in situ* hybridization

## Partial Polyhedrin Fusion Expression Enhance the Production of Recombinant Protein in Baculovirus

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Polyhedrin is the major component of the nuclear viral occlusions produced during replication of the baculovirus *Autographa californica* multicapsid nuclear polyhedrosis virus (AcMNPV). To enhance the expression level of baculovirus vector system, we constructed several fusion vectors using various fragments of the polyhedrin. The polyhedrin fragments were genetically fused to the enhanced green fluorescent protein (eGFP) under the control of polyhedrin promoter, and their expressions were analyzed in Sf21 insect cells. Expression of the fusion protein was identified by SDS-PAGE and Western blot analysis using anti-GFP and anti-Polyhedrin. The expression level of eGFP was markedly increased by the fusion of partial polyhedrin. Also, the fluorescence intensity of fusion proteins was higher than that of non-fusion protein. Confocal laser scanning microscopy demonstrated that fusion proteins were localized to the cytosol or nucleus of insect cells. In additional, the glycoprotein E2 (gE2) of classical swine fever virus (CSFV) expressed by the these vectors was dramatically increased and its immunogenicity was proofed using experimental animal guinea pigs that were immunized with the partial polyhedrin containing gE2. This study provides a new option for the higher expression of useful foreign recombinant protein by using the partial polyhedrin in BEVS.

**Key words:** Baculovirus Expression Vector System (BEVS), Polyhedrin, Fusion protein, Localization, CSFV-gE2

## The *Wolbachia* bacterial density determines the sex in *Trichogramma kaykai* (Hymenoptera: Trichogrammatidae)

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The *Wolbachia* bacterium is known to induce reproductive anomalies in various insect taxa such as cytoplasmic incompatibility, feminization, male killing and parthenogenesis. It is hypothesized that the degree of reproductive anomalies is dependent on the bacterial infection density.

In this study, we attempted to test the hypothesis using the tiny egg wasp, *Trichogramma kaykai* that has served as the model system of parthenogenesis where an unfertilized egg develops into a female due to the bacterial infection. So far this is only found in haplodiploid organisms.

The results show that 1) as mothers aged, they started producing male offspring, 2) the sex ratio was negatively correlated with the bacterial infection density, 3) female offspring were more than six times heavily infected with *Wolbachia* than male offspring in the species. In conclusion, female offspring production, parthenogenesis, is as a function of the *Wolbachia* bacterial density in this species.

**Key words:** *Wolbachia*, *Trichogramma kaykai*, bacterial density, sex ratio, real-time quantitative PCR

## Complete Genome of *Bombyx mori* Nucleopolyhedrovirus-K1 and K4 Strains Isolated in Korea

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The four genetically distinct isolates have been identified previously from *Bombyx mori* nucleopolyhedroviruses (BmNPVs) isolated in Korea. To further understand the complex of viruses infecting *Bombyx mori*, the genome of BmNPV-K1 and K4 strains was completely sequenced and analyzed in comparison with the genome of other sequenced baculoviruses including previously reported BmNPV. BmNPV-K1 consisted of 127,542 bp and 133 open reading frames (ORFs) of 150 nucleotides or longer with minimal overlap have been identified. In contrast, BmNPV-K4 consisted of 128,615 bp and 134 open reading frames (ORFs). Although gene arrangement is virtually identical, the genome of BmNPV-K4 is 1,073 bp longer than BmNPV-K1. This was related to the more existence of *bro* genes in BmNPV-K4. To investigate the relationship between BmNPV-K1 and K4, phylogenetic analysis with each member of the paired ORFs was performed. The sequence data suggest that BmNPV-K1 and BmNPV-K4 are closely related but have diverged and evolved into two separate strains. This was study to identify highly related but separately evolving viruses in the same insect host and geographic location. We are currently comparing the differences of these BmNPV genomes to elucidate characteristics of each virus.

**Key words:** *Bombyx mori*, nucleopolyhedrovirus, *bro* gene

## Modeling potential global distribution of a leafroller, *Epiphyas postvittana* (Lepidoptera: Tortricidae) using CLIMEX and a new multiple-model system

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Light brown apple moth, *Epiphyas postvittana*, is a significant horticultural pest native to Australia, and currently with a limited global distribution. However it can tolerate very heterogeneous climatic and vegetation conditions and has recently invaded California with considerable consequences for US international and domestic trade. By comparing the climatic conditions of its native (Australia) and long-established (New Zealand) ranges to the rest of the world using CLIMEX, it was suggested that *E. postvittana* has potential to establish mainly in countries in Central and South America, southern Africa, west Europe and South-east Asia. However, the predicted global distribution of *E. postvittana* using a new multiple-species-distribution model system suggested that there are additional climatically suitable areas around the world where this species could potentially survive and establish. Our study provides basic but important information for further assessment of the establishment capacity of this species in new habitats, which will provide the knowledge required to make science-based decisions in biosecurity.

**Key words:** biosecurity, quarantine pest, exotic species, invasive species, ecological model, distribution prediction, machine learning, support-vector machine

## 주남저수지의 육상 곤충상

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경남의 대표적 습지인 주남저수지 중 주남저수지(3개지점), 동판저수지(3개지점), 산남저수지(3개지점) 및 인공연못(전체)을 대상으로 2010년 5월부터 10월까지 육상곤충의 다양성과 군집특성을 조사하였다. 총 12목 77과 273종이 조사되었는데, 나비목이 61종, 딱정벌레목이 54종, 노린재목이 34종이었다. 개체수는 딱정벌레목이 1450개체로 가장 많았고 그 다음이 잠자리목 1274개체, 나비목 878개체 순이었다. 조사지점별로는 주남저수지 169종, 동판저수지 185종, 산남저수지 154종이 조사되어 비슷한 양상을 보였으나 인공연못에서는 86종이 조사되었다. 전지점을 종합해 볼 때 동판저수지와 산남저수지에서 우점종인 일본잎벌레가 우점종이었는데, 이는 수생식물인 마름이 기주이기 때문에 일본잎벌레가 습지환경에 잘 적응했기 때문으로 생각된다. 곤충 군집 분석 결과 우점도지수(DI)는 인공연못이 0.25로 가장 높고 주남저수지가 0.08로 가장 낮았다. 다양도지수(H')는 주남저수지가 4.48, 동판저수지가 4.44, 산남저수지가 4.28, 인공연못이 3.87로 모두 높았다. 한편 지점별 우점도지수, 다양도지수, 균등도는 월별로 큰 차이를 보이지 않았는데 이는 주남저수지가 계절적으로도 곤충이 지속적으로 출현하는 안정된 곤충상을 갖고 있음을 의미한다고 할 수 있다.

**검색어:** 주남저수지, 곤충상, 생태지수, 우점도지수, 다양도지수

## Spring emergence pattern and its forecasting of *Grapholita molesta* (Busck) (Lepidoptera: Tortricidae) in stone fruit orchards

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The study was conducted to investigate the spring emergence pattern of *G. molesta* and to forecast the emerging time of overwintering *G. molesta* on tree fruit orchards. *G. molesta* is one of major insect pests on fruit trees in Korea. The host range of *G. molesta* includes many economically important tree fruit plants such as apple, pear, peach and plum. The overwintering *G. molesta* emerge from late March as an adult lay eggs on the shoot of peach or fruits of apple, plum and peach. Therefore, it is important to understand the biofix and to forecast the emerging peak period of overwintering *G. molesta* for establishing the pest management strategy. The pheromone trap of *G. molesta* has been utilized to monitor the population density in apple orchard. The commercial stick trap (GreenAgroTech) and lure (Z8-12:AC, E8-12:Ac, Z8-12:OH, 95:5:1) was set to monitor the population density of *G. molesta* on each place (56 different fruit orchards). The record of temperature was received from meteorological center close to monitoring orchards. The parameters for forecasting the emerging time and peak period of overwintering *G. molesta* were calculated from the results of Yang et al (1997 and 2001). Although the estimated biofix of *G. molesta* was not fitted well, the peak period of overwintering *G. molesta* was explained by linear regression model. The spring emergence pattern of *G. molesta* was presented differently related to host plant and geographical location. The peak period of *G. molesta* at the same monitoring county was presented differently according to host plant. The synchronization between host plant and *G. molesta* may be studied to figure out the spring emerging time of overwintering *G. molesta*.

**Key words:** *Grapholita molesta*, pheromone trap, spring emergence pattern, temperature, fruit tree

## 국내·외 응용곤충학 관련 학술논문집간 통계적 처리기법 비교 연구

손진오, 박정준, 김수경, 김기웅, 조기종

고려대학교 환경생태공학부

오늘날 통계적 사고와 통계적 기법의 활용은 학문분야에 있어 보편화되고 있는 추세이다. 또한, 국내 학술지가 국제 학술지로 격상되고 있는 현재, 논문에서의 통계 기법 사용의 적정성을 점검해 볼 필요가 있을 것이다. 본 논문에서는 응용곤충학 관련 학술논문집간 통계적 기법의 사용빈도를 비교해봄으로써 국내논문의 통계 기법 사용의 현재 위치에 대해 고찰하고, 국내논문이 나아갈 방향에 대해 모색해보았다. 본 연구에는 통계 빈도에 대한 조사를 비교하는 데에는 2005년에서 2009년까지 5년간 국내·외 학술논문에 기재된 논문 대상으로 Fisher's exact test를 사용하였다. 우선 국내와 일본 학술논문집간 비교 결과, 2007년까지는 통계적 처리기법의 사용빈도에서 유의한 차이를 보였으나 그 이후에는 유의한 차이가 나타나지 않았다. 국내와 네덜란드의 학술논문집간 비교에서는 2009년을 제외하고는 통계적 처리기법의 사용빈도에서 모두 차이가 있는 것으로 나왔다. 참고적으로 일본과 네덜란드의 비교에서는 통계적 처리기법의 사용빈도에서 차이가 없었다. 이러한 결과를 토대로, 국내 학술논문집에서의 통계적 기법의 사용빈도가 점차 국외 학술논문집들과 비슷해지는 과정에 있다는 것을 알 수 있었다. 따라서 논문에서의 통계적 기법을 사용하는 것에 더욱 신중하고 노력을 기울일 필요가 있겠다.

**검색어:** 응용곤충학, Fisher's exact test, 통계적 처리기법 사용 빈도



## Effect of host genetic background on the offspring sex ratio in the *Wolbachia* infected *Trichogramma kaykai*

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The  $\alpha$ -proteobacterium *Wolbachia pipientis* infects a wide range of arthropods and filarial nematodes. *Wolbachia* is maternally inherited and is known to induce reproductive anomalies such as cytoplasmic incompatibility, feminization, male killing and parthenogenesis induction (PI). *Trichogramma kaykai* is a tiny wasp that parasitizes on lepidopteran eggs. When a female of the wasp is infected with PI-*Wolbachia*, the female produces female offspring via gamete duplication without the aid of sperm. As she ages, however, the fraction of male offspring increases. In this study, we investigated the effect of host genetic background on the expression of sex ratio between isofemale lines. Virgin females of six isofemale lines were allowed to lay eggs individually for 10 days.

There was the positive relationship between female age and the offspring sex ratio. Furthermore, the sex ratio was significantly different among isofemale lines, implying that the host genetic background had an effect on the sex ratio. Based on the results, evolution of symbiosis in terms of sex ratio and future experimental design are discussed.

**Key words:** *Wolbachia*, *Trichogramma kaykai*, parthenogenesis, host genetic background, sex ratio





## 포스터 발표

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P001

## Morphological and Molecular Diagnosis of *Meloidogyne* spp. from Imported Plants in Quarantine

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Species of root knot nematodes, *Meloidogyne* spp. were identified through the PCR amplification and sequence analysis of mitochondrial DNA (mtDNA) region between COII and lrRNA genes. Root knot nematodes were extracted from 5 plant samples [kiwi (Japan), rhododendron (Japan), cornus (Japan), ficus (China) and jasmine (Vietnam)] that were collected from Plant Quarantine Station in Korea. At first, species was identified using morphological characters, such as the length and shape of stylet, the tail length and the perineal patterns. Secondary, single individuals of either female and juvenile collected from plant tissues were used for PCR and further sequencing analysis. The results showed that cornus, jasmine and ficus plants were infected by *M. incognita*, and kiwi and rhododendron plants were infected by *M. interlobii*.

**Key words:** Identification, *Meloidogyne* spp, PCR, Quarantine

P002

## A checklist of tribe Phylini (Heteroptera: Miridae: Phylinae) in the Korean Peninsula

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The tribe Phylini (Miridae: Phylinae) is revised in the Korean Peninsula. A total of 65 species in 20 genera are confirmed to exist in this territory. Five genera and 20 species are recognized for the first time in Korea, including a new genus and 6 new species: Gen. nov. sp. nov.1; *Psallus* sp. nov.1, *P.* sp. nov.2, and *P.* sp. nov.3; and *Moissonia* sp. nov.1 and *M.* sp. nov.2. Herein, checklist for the Korean Peninsula is reconstructed with its geographical distribution, and short discussion.

**Key words:** Miridae, Phylinae, Phylini, a new genus, new species, new records, checklist, the Korea Peninsula.

P003

## Morphological and Molecular Comparison of Tetranychid Mites in Korea and Identification of Three New Species

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Tetranychid mites are one of the most diverse group including at least 1,200 species in the world. Species identification is difficult due to the small size and similar morphology within the group. We collected 17 species of spider mites from various host plants in different regions of Korea and determined species identity by the comparison of morphological characters and nucleotide sequences of internal transcribed spacer 2 (ITS2) and the cytochrome oxidase subunit I (COI). In addition, we report three new species that were firstly identified in Korea. *Amphitetranynchus quercivorus* (Ehara and Gotoh) was collected from Mongolian oak plant in Daegu, *Schizotetranychus miscanthi* Saito was from the common reed plant in Ulleungdo, and *S. cercidiphylli* Ehara was from Bamboo plant in Jeju. Morphological identification of three species were similar with those of Japanese samples, but the ITS2 and COI sequences of *A. quercivorus* and the COI sequence of *S. miscanthi* were different with Japanese species at the rates of 1/419, 2/331 and 3/332 nucleotides, respectively. *S. cercidiphylli* can be identified by the aedeagus shape of males but we firstly sequenced ITS2 and COI of this species. Our results can be used for the identification of spider mites which are important in plant quarantine.

**Key words:** COI, ITS2, Molecular phylogeny, Spider mites, Tetranychid

P004

**The Complete Mitochondrial Genomes of the Tobacco cutworm, *Spodoptera litura* (Lepidoptera: Noctuoidea) and the Rice Leaf Roller, *Cnaphalocrocis medinalis* (Lepidoptera: Pyralidae), and Reconstruction of Phylogenetic Relationships among Lepidoptera**

**Xinlong Wan, Min Jee Kim and Iksoo Kim**

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Two complete mitochondrial genomes of the tobacco cutworm, *Spodoptera litura* (Lepidoptera: Noctuoidea) and the rice leaf roller, *Cnaphalocrocis medinalis* (Lepidoptera: Pyralidae), were sequenced. Each 15,388 bp and 15,368 bp-long genome contained both the lepidopteran specific gene arrangement that differ from the most common arrangement of insects by the movement of tRNA<sup>Met</sup> to a position 5'-upstream of tRNA<sup>Ile</sup>. Neither of the species have typical COI start codon. Instead, the CGA (arginine) sequence that is commonly present in other lepidopterans was also found both in *S. litura* and *C. medinalis*. The evolutionary rates among 13 protein-coding genes (PCGs) in Lepidoptera showed ATP8 the highest, whereas COI the lowest. The high A+T-content, which is characteristic of mitochondrial genome was well reflected in the two lepidopteran mitochondrial genomes: higher frequency of A/T-rich codons, severe A/T bias in 3rd codon position, and extremely high A/T content in the A+T-rich region. Because insect mitochondrial genomes harbor biased nucleotide and resultantly biased amino acid sequences, phylogenetic inference is often misled by them. Although each recoded and unrecoded datasets for nucleotide sequences and amino acid sequences of PCGs provided overall identical topology, regardless of recoded scheme, each nucleotide and amino acid dataset provided difference in the status of Macro-lepidoptera, providing a monophyletic group by amino acid dataset, whereas non-monophyletic group by nucleotide dataset.

**Key words:** Mitochondrial genome, *Spodoptera litura*, *Cnaphalocrocis medinalis*, Phylogenetic analysis



## Phylogenetic Relationships among the Nymphalidae (Lepidoptera: Papilionoidea) Inferred from COI, EF1- $\alpha$ , and 16S rRNA genes

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The phylogenetic relationships among the Nymphalidae (Lepidoptera: Papilionoidea) have been controversial. The present study sequenced approximately 1,099 bp from cytochrome oxidase subunit I (COI), 1,336 ~ 1,551 bp from 16S ribosomal RNA (16S rRNA), and 1,066 bp from elongation factor-1 alpha (EF-1 $\alpha$ ) in 80 species belonging to seven subfamilies (Linmenitidinae, Heliconiinae, Nymphalinae, Apaturinae, Libytheinae, Satyrinae, and Danainae) of Nymphalidae, along with those of six lycaenid species as outgroups. The average base compositions for the three genes (COI, 16S rRNA, and EF-1 $\alpha$ ) are as follows: A (30.6%, 38.8%, and 25.8%), G (14.7, 5.2%, and 23.6%), T (39.8%, 45.2%, and 23.4%), and C (14.9%, 10.8%, and 27.3%). This result shows the A/T bias in the mitochondrial genes, but not for the nuclear EF-1 $\alpha$ . Between the two mitochondrial genes, the 16S rRNA gene evidenced a significantly higher A/T content than was detected in the COI gene. These sequences were subjected to phylogenetic reconstruction via Bayesian Inference (BI) and Maximum Likelihood (ML) algorithms. Both analyses concordantly supported the subfamilial relationships of (((((Linmenitidinae + Heliconiinae) + (Nymphalinae + Apaturinae)) + Libytheinae) + Satyrinae) + Danainae), along with highly supported monophyletics of tribes within subfamilies. This result is largely consistent with a previous study performed with a large sequence information and morphological characters, except for the position of Libytheinae, which was suggested to be the basal lineage of Nymphalidae.

**Key words:** Nymphalidae, Phylogenetic analysis, COI, ELF-1 $\alpha$ , 16S rRNA

P006

## **Integrative Taxonomy of *Asiopodabrus fragiliformis* (Kang and Kim, 2000) (Coleoptera: Cantharidae) Combining Morphological and Molecular Data**

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In traditional taxonomy on the family Cantharidae, color pattern of the body and the structure of the male genitalia have been often used as diagnostic characters in identification of the specific level. However, these characters caused the difficulty in identifying the female in case a species was described only by male specimens or has the several color types among individuals. In this study, we attempted to evaluate the species reality of *Asiopodabrus fragiliformis* which was often difficult to be identified due to individual variation in color pattern and lack of information of female, through searching for new morphological diagnostic characters as well as DNA barcoding analysis, including their closely relative species from Russia and Japan. The results showed that *A. fragiliformis* was represented as three clusters strongly supported by high value of boots trap (>99%) and over 3% branch length. The pairwise distances between species of *Asiopodabrus* were detected larger, ranged from 3.4–9.5%, than the intragroup distance ranged from 0–2.9% indicating presence of a barcoding gap. And then, the three clusters were respectively determined as *A. fragiliformis*, *A. kurvatovi* and a new species through the analysis of morphology and COI gene. Therefore, we suggest that the species delineation on polymorphic species and the female specimens of closely resembling species would be more exactly and effectively determined if DNA barcoding and the traditional taxonomy are used as complementary methods for identification.

**Key words:** *A. fragiliformis*, Cantharidae, DNA barcoding, polymorphic species, female identification

P007

## 분자분류기술을 이용한 형태적 혼동종의 진단 II: 범부전나비(*Rapala caerulea*)와 울릉범부전나비 (*Rapala arata*)

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범부전나비(*Rapala caerulea*)와 울릉범부전나비(*Rapala arata*)는 형태적 유사성이 높은 종들로 일반적으로 날개 윗면의 색으로 구분되어 왔다. 또한, 지리적 분포 특성으로 볼 때 범부전나비는 중국 중부, 북동부에서 한반도(울릉도, 제주도 제외)까지 서식하는 반면, 울릉범부전나비는 극동러시아, 중국 동북부, 한국의 울릉도와 제주도, 일본까지 출현한다. 두 종의 분포가 겹치는 한국에서는 날개의 체색만으로는 두 종의 진단이 모호하므로 뒷날개 밑면 후연의 점무늬로 구분한다. 즉, 2개의 흑점무늬를 갖는 종은 범부전나비, 4개의 흑점무늬를 띤 종은 울릉범부전나비로 구분하고 있다. 하지만, 두 종 각각의 일부 개체에서는 흑점무늬의 배열에서 중간형이 지속적으로 출현하는 것이 확인되어왔다. 이처럼 두 종간의 형태적 진단 형질의 부분적 중복으로 인한 모호성을 극복하기 위하여 COI유전자를 이용하여 두 종의 지역집단(한국 3개 집단, 일본 1개 집단) 26개체에 대한 DNA 바코딩 분석을 실시하였다. 하지만 그 결과로 분석된 26개체에 대한 COI 서열 차이는 0.0-0.3%로 극히 작았을 뿐 이었다. 특히, 0.2-0.3%의 서열변이를 나타낸 범부전나비의 경상북도 울진산 2개체의 경우도 1개의 염기만이 차이가 있었을 뿐 나머지 서열은 모두 똑같은 것으로 나타났다. 따라서 2종 간에 barcoding gap을 형성할 만큼의 차이는 전혀 없었으며, 두 종은 동일종의 집단으로서 집단 간 변이도 크지 않았던 것으로 해석되었다. 이에 따라서 향후 형태형질의 추가적 분석을 통해 종합 분류를 수행하면서 동물이명 처리가 필요할 것으로 판단되었다.

**검색어:** 범부전나비, 울릉범부전나비, 형태적 중간형, DNA 바코드

## 한국산 작은초원하늘소 (딱정벌레목 : 하늘소과)의 분류학적 문제 제기

권오창, 이호단, 이영보, 박해철, 김남정

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국내에서 *Theophilea cylindricollis* Pic, 1985로 학명을 적용해온 작은초원하늘소에 대한 분류학적인 문제가 있음이 최근에 확인되었다. *Theophilea cylindricollis* Pic은 목하늘소아과(Lamiinae) 초원하늘소속 (Agapantini) 작은초원하늘소속 (*Theophilea* Pic, 1985)의 일원이었으며, 동일 속에는 세계적으로 2종만이 알려져 있다. 하지만 국내에서 알려져 온 작은초원하늘소를 형태분류학적으로 검토한 결과, 진정한 *Theophilea cylindricollis* Pic뿐 아니라 초원하늘소속 (Agapantini Mulsant)의 정의와도 명확한 형태적 차이점이 있었다. 오히려 원통하늘소속 (Hippopsini)의 정의에 가까운 것으로 판단되어 해당 속의 근연 4속을 비교 검토해 본 결과, 형태적으로 원통하늘소속 (*Pseudcalamobius*)에 가깝지만 더듬이의 길이와 눈의 형태에서 뚜렷한 차이가 있어 향후 별도의 속으로 구분되어야 할 필요성이 제기되었다.

**검색어:** 분류, 초원하늘소, 하늘소과, 목하늘소아과, 원통하늘소속

P009

## Taxonomic Review of the Genus *Oberea* Dejean, 1835 (Coleoptera: Cerambycidae: Lamiinae) from South Korea

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The genus *Oberea* belongs to the tribe Saperdini (Coleoptera: Cerambycidae) and contains about 270 described species in the world.

The genus can be defined by the combination of the following characters: body elongate, cylindrical; legs very short, apex of hind femur not reaching beyond abdominal sternite II.

*O. vittata* Blessig was reconfirmed its distribution in South Korea during the study. Two species are newly reported here: *O. heyrovskyi* Pic and *O. tsuyukii* Takashi & Ohbayashi.

We provide a revised checklist of 12 species and a pictorial key to species for the identification, with diagnostic characters of *O. heyrovskyi* and *O. tsuyukii*.

**Key words:** Cerambycidae, Lamiinae, *Oberea*, new record, Korea

P010

## Development of microsatellite loci from the beet armyworm, *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae)

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Ten novel microsatellite loci were isolated and characterized from the beet armyworm, *Spodoptera exigua*. The isolated loci are polymorphic, with 2~12 alleles in 18 individuals from several populations in Korea. All 18 individuals had different multilocus genotypes with heterozygosity ranging from 0.089 to 0.843. Nine of 10 loci kept the Hardy-Weinberg equilibrium in adjusted significance thresholds. We report the development of microsatellite markers for *S. exigua* potentially suitable for further studies of population structure, dispersal, and host relationship.

**Key words:** *Spodoptera exigua*, microsatellite, population genetics, beet armyworm

P011

## 한반도 발생 잠자리(Odonata)의 분자계통 연구

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잠자리목은 3개 아목(실잠자리아목, 잠자리아목 및 옛잠자리아목)으로 구성되어 있다. 형태형질 및 분자마커형질에 의한 다양한 가설이 제시된 가운데 실잠자리아목 및 잠자리아목의 단계통 여부, 옛잠자리아목의 계통분류학적 위치에 대해서 그리고 각 아목내 상과별 및 과별 관계에 대해서 다양한 연구결과가 존재하는 실정이다. 본 연구는 잠자리목내 7개 상과, 10개 과 총 71종을 대상으로 COI, 16S rRNA, 28S rRNA 및 EF1- $\alpha$  유전자의 염기서열을 이용하여 한반도 내 분포하는 잠자리목내 두 아목간 및 아목내 분류군간의 계통분석을 수행하였다. 계통수 작성은 Maximum Likelihood (ML), Bayesian Inference (BI), Maximum Parsimony (MP) 및 Neighbor Joining (NJ)법을 이용하였다. 그 결과, 잠자리아목은 모든 분석에서 비교적 높은 노드 수치로 (78~100) 단계통을 형성하였다. 반면 실잠자리아목은 MP 및 NJ 분석 결과 단계통을 형성하였으나 ML 및 BI법을 이용한 분석 결과 청실잠자리과 (Lestidae)가 잠자리아목의 기저부에 위치함으로 실잠자리아목의 비단계통 가능성을 제시하였으며 이러한 결과는 타 연구에서 일부 제시된 바 있다. 보다 신뢰성 있는 계통도 확보를 위하여 TOPOLOGY TEST 수행 결과 BI법에 의해 작성된 계통도가 상대적으로 높은 수치로 지지됨을 확인하였다 (ELW, 0.912762; BP, 0.9129; KH, 1; SH, 1; WSH, 1 및 AU, 0.9182624). 추후 보다 심도 있는 분석을 수행함으로 진화적 관련을 잘 반영하는 계통도를 작성할 수 있을 것으로 사료된다.

**검색어:** 잠자리목, 계통분석, COI, 16S rRNA, 28S rRNA, EF1- $\alpha$

P012

## Taxonomic review of the tribe Oxyptilini (Lepidoptera, Pterophoridae) from Korea

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The tribe Oxyptilini Bigot *et al.* 1998 (Lepidoptera: Pterophoridae) consists of fifteen genera with more than 100 species worldwide. Almost half of them are mainly distributed in Palaearctic Region, others are in Afrotropical, Oriental, and Nearctic regions, and less than 10 species are in Australasian, Neotropical, and Pacific regions (Gielis 2003).

Nevertheless, it has been poorly known in the Asian part of Palaearctic region, with five species in Japan (Yano 1963), two species in Russia (Sinev 2008), and one species in China (Li *et al.* 2003). In Korea, only one species, *Stenodacma pyrrhodes* (Meyrick 1889), has been reported from North Korea (Arenberger 1991).

During this study, four genera (*Capperia* Tutt, *Oxyptilus* Zeller, *Procapperia* Adamczewski, and *Tomotilus* Yano), are recognized for the first time from Korea, and a new generic combination of *Tomotilus celebrates* (Merick 1932), **comb. nov.**, is proposed.

**Key words:** Pterophoridae, Oxyptilini, Korea.



P013

## **Two unrecorded species of Oribatid mite in Ulleung Island, *Punctoribates hexagonus* Berlese and *Galumna cuneata* Aoki**

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From the soil samples collected at Seonginbong in Ulleung Island two unrecorded species of oribatid mite, *Punctoribates hexagonus* Berlese and *Galumna cuneata* Aoki were identified. Genus *Punctoribates* Berlese (1908) are rather small, dark brown, and ball-shaped as adults inhabiting mainly terrestrial ecosystem, but some species live in wet habitats and other mosses at the edge of lakes (Seniczak and Seniczak, 2008). The members of Galumnidae is one of the largest groups of oribatid mites with a world - wide distribution. They are ball-shaped, both the juvenile and adult stages. The sclerotized integument of adults are brown to black. Member of this family are fairly abundant in litter or upper layers of forest soils and commonly distributed in pasture soils of open habitats (Bayartogtokh and Weigmann, 2005). Soil samples were collected from five random samples at 5cm depth consisting of one sample unit. The abundances of soil microarthropods collected from acari and collembola were consisted of 31% and 32%, respectively. We collected 11 species, 9 families of oribatid mite (Acari: Oribatida) from the research site.

**Key words:** oribatid mite, *Punctoribates hexagonus*, Galumnidae, *Galumna cuneata*, juvenile

P014

## Isolation and characterization of 15 microsatellite loci from *Lycorma delicatula* (Hemiptera: Fulgoridae)

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*Lycorma delicatula* (White 1845), which has been recently introduced into Korea, is a notorious pest on grapes. This invasive insect has rapidly spread throughout central and southern Korea. To date, we have no behavioral or population genetics information, such as invasion routes and subsequent dispersal rates in Korea, to help understand and control populations of *L. delicatula*. Here, we have developed 15 novel microsatellite loci for *L. delicatula*. The isolated loci were polymorphic, with 2 to 19 alleles in 42 individuals from a single population in Cheonan. The analyses revealed that all 42 individuals had different multilocus genotypes with heterozygosity ranging from 0.214 to 0.866. Eleven of the 15 loci did not deviate significantly from Hardy-Weinberg equilibrium. The isolated markers will facilitate population genetic studies of *L. delicatula*.

**Key words:** insect pest, invasive species, polymorphic microsatellite, population genetics

P015

## Population genetic structure of the soybean aphid from Asia and North America based on microsatellites

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The soybean aphid, *Aphis glycines* Matsumura, was recently introduced from Asia into North America (NA) where it has become a serious pest of soybeans. This invasive pest has rapidly spread throughout the midwestern United States and southern Canada since 2000. We examined 585 individuals obtained from 23 different collections in USA, Korea, China, and Japan using eight microsatellite loci. Based on analysis of multilocus genotype, gene diversity and number of alleles in NA were averaging 0.40 and 2.70, whereas in Asia averaging 0.55 and 4.32, respectively. The factorial correspondence analysis displayed that some Korean populations were closely related to the NA populations. Structure analysis resulted in two conspicuous clusters, NA and Asia, as the most likelihood number of clusters ( $K$ ). Bayesian assignment tests revealed that Osan and Milyang populations were most likely assigned to the NA populations. Bottleneck test did not show significance of genetic bottleneck in all populations. We also discuss the invasive history of the soybean aphid in light of population genetics.

**Key words:** aphid, *Aphis glycines*, invasive species, microsatellite, population genetics

P016

## 캄보디아 동부와 서부 곤충다양성 : 나비목 Insect Diversity of Eastern and Western part of Cambodia : Lepidoptera

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캄보디아는 동양구에 위치한 국가로 북동쪽으로 라오스, 동쪽과 남동쪽으로 베트남, 북쪽과 서쪽으로 태국과 접하고 있다. 육지면적(181,035km<sup>2</sup>)의 3/4은 중부의 넓은 평야들과 남쪽으로 국토의 동부를 가로질러 흐르는 메콩강이 큰 비중을 차지한다. 기후는 건기와 우기로 나누어지는 전형적인 열대몬순기후이다. 캄보디아는 독립(1945년) 때까지 간헐적인 생물상 조사가 이루어졌으나, 이후 내전이 발발하여 약 45년 동안 생물다양성 연구가 거의 진행되지 못하였다. 현재 국제적인 NGO단체들이 보호구역을 중심으로 연구를 진행하고 있으나, 여전히 많은 지역의 생물다양성 조사가 미흡하다. 또한 곤충 다양성연구는 더더욱 미비하여, 신종 및 미기록종의 발견이 기대된다.

본 연구는 2010년 4월 30일 ~ 5월 6일까지 2010년 10월 5일 ~ 10월 10일까지 캄보디아 동부지역인 Pro. Mondulkiri Trapeang Thmear와 Seima Biodiversity Conservation Area와 캄보디아 서부지역인 Prov. Pursat, Rovieang and Osom에서 Sweeping, Light trap 등 다양한 방법을 이용하여 곤충상을 조사한 결과, 나비목은 총 92종을 채집하였으며, 동부에서는 76종이 채집되었고, 서부에서는 30종이 채집되었다.

**검색어:** 곤충 다양성, 나비목, 미기록종, Seima, Pursat, 캄보디아

P017

## Reinstatement of *Scolytoplatypus sinensis* Tsai & Huang 1965 (Curculionidae: Scolytinae), based on molecular and morphological evidence

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The Korean record of *Scolytoplatypus mikado* Blandford 1893 is originated from Murayama (1929) whereas Wood(1989) synonymized *S. sinensis* Tsai & Huang 1965 as a junior synonym of *S. mikado* Blandford 1893. In 2010, the authors collected several specimens from Korea and Japan and found considerable morphological differences between *S. sinensis* and *S. mikado*: the process on the prosternum, the pubescences on the procoxae, and the shape of the male elytral declivity. Comparing the Cytochrome Oxidase I and 16S rRNA gene, we also found the genetical gap between the South Korean specimens (= *S. sinensis*, with the Japanese sample from Mt. Tsukubasan) and the sample from Mt. Yamizosan, Japan (= *S. mikado*). Accordingly, *S. sinensis* Tsai & Huang 1965 is here reinstated.

**Key words:** *Scolytoplatypus sinensis*, Cytochrome Oxidase I, 16S rRNA gene, reinstatement

P018

## Literature review of Limacodidae (Lepidoptera: Zygaenoidea) in Korea

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The family Limacodidae, which is generally known with a Korean common name, ‘Sswaegi’, belongs to the superfamily Zygaenoidea. Most species have strong hair-like bristles, which causes painful skin irritation on outer surface of larval stages.

Members of the family are small to medium sized moths and can be defined with the combination of the following characteristics: larvae without crochets, adults with R3, R4 and R5 veins of the forewing stalked and papillae anales disk-shaped.

The family contains approximately 1,000 species of 400 genera from the world and a number of species recorded from the tropical regions.

In Korea, seven species were studied by Fixen (1887) for the first time. Since then, some fragmentary reports and taxonomic studies were made by several lepidopterists.

Although there are 25 species of 19 genera known from Korea, comprehensive study for Korean limacodids has not carried out up to date.

As the preliminary step for a revisional study on Korean species of the family, a literature review has been done, and some corrections were made on incorrect scientific names in ‘Checklist of Korean insects (2010)’, which was most recently published.

**Key words:** Checklist, Korea, Limacodidae, literature review, Zygaenoidea

P019

## Introduction of Cambodian Beetles (IV)

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Cambodia covers an area of 181,035 sq km, among them, forests cover 53 percent, so there are abundant Insect diversities.

Collecting expeditions of Insect were conducted from towns of Osam (first base camp, N 12° 04' 51.7" E 103° 12' 30.5" alt. : 549m) and Roveang (second base camp N 12° 19' 06.5" E 103° 3' 03.8" alt. : 53m) in Pursat Province, western part of Cambodia. As protected forest from government, these areas were almost natural conservation field. Pitfall trap, sweeping method, light trap and searching *etc.* were used to collect insect. Specially in this expedition, large or big sized beetles, more than 5cm body length, for example, Lucanidae, Cerambycidae, Elateridae *etc.*, mostly collected from light trap in deep forest.

Materials are expected more than 100 species belonging to 20 families but it was difficult to identification because of lack of references of this areas. Maybe lots of new or new recorded species will found from Cambodia. Among Coleoptera species, with big sized beetles as the central figure, photos for species of dominant, rare, nominated species of new or new recorded were introduced, and also collecting sites and activities were presented.

**Key words:** Beetles, Insect diversity, Coleoptera, Cambodia

## Morphology of the egg and first instar larva of *Smaragdina nipponensis* (Chûjô) (Coleoptera: Chrysomelidae: Clytrinae)

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Among the Coleoptera, case bearing is found in four related subfamilies of the Chrysomelidae, the so-called Camptosomates: Clytrinae, Cryptocephalinae, Chlamisinae, and Lamprosomatinae (Böving and Craighead, 1931). Adults of case-bearing chrysomelids feed on foliage of a variety of eudicots (Erber, 1988), but their larvae often show departures from strict phytophagy. Besides those with true herbivore larvae, that feed on green plant parts and complete development on the host plant, the larvae of most species live on the ground, in leaf litter, and feed on dry vegetable material and detritus (Erber, 1988; Brown and Funk, 2005). The larvae of some clytrine species live in ant nests (Erber, 1988; Brothers et al., 2000), but besides these mirmecophiles, many other clytrine larvae live in leaf litter and some few others on plants (Erber, 1988; Jolivet, 1988).

The genus *Smaragdina* Chevrolat is distributed in the Palearctic region, and in the Oriental region (Chûjô & Kimoto, 1961; Erber & Medvedev, 1999; Gök, 2003; Maican, 2005, 2006). Forth-three *Smaragdina* species are distributed throughout northeast Asia, from Korea to Japan (Gressitt & Kimoto, 1961; Kimoto & Takizawa, 1994, 1997). In Korea a total of 5 species were known by Lee and An (2001). Recently, *Smaragdina nipponensis* Chûjô is newly recorded by Park et al. (2011). However, for the clytrine larvae has never been studied from Korea.

The present study contains the description of the egg and first instar larva of *S. nipponensis* with notes on biology of adults and larvae, observes in natural conditions and in laboratory.

**Key words:** Chrysomelidae, Clytrinae, First instar larva, *Smaragdina nipponensis*



P021

## Two Species of the Family Pyralidae (Lepidoptera) New to Korea

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Bae *et al.* (2008) made a illustrated catalogue of the family Pyralidae in Korea, including 349 known species up to date. During the survey of the lepidopterous insects in Jeju island, we found two unrecorded species, *Daulia afralis* Walker and *Herpetogramma cynaralis* Walker, from Korea.

In this study, we report the two newly recorded species with illustration of adult and genitalia, including available information on distributional range and synonymy.

The material examined is now deposited in the Natural History Museum, Hannam University. The genitalia of the species were mounted in Euparal media and photographed with a AxioCam MRc 5 digital camera attached to a Carl Zeiss microscope, with an Axio Imager A1. The color standard for the re-description of adults was based on the Methuen Handbook of Colour.

**Key words:** *Daulia afralis*, *Herpetogramma cynaralis*, Crambidae, Korea, new record

P022

## Molecular identification of dipteran pest from shiitake mushroom bedlogs

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Cecidomyiidae and Sciaridae (Diptera: Sciaroidea) are mostly mycophagous, feeding on decaying plant materials and fungi. On the shiitake bedlogs, great number of larvae of the species cause serious damage, feeding on the mycelium of the shiitake mushroom. We confirmed five species emerged from the shiitake bedlogs, which are two cecidomyiids and three sciarids. Using the DNA barcoding, the mitochondrial cytochrome c oxidase subunit I (COI) region (658 bp), the larvae and adult flies were identified, and *Camptomyia corticalis* was confirmed as a major pest on shiitake mushroom.

**Key words:** Shiitake mushroom, *Camptomyia corticalis*, Molecular identification, DNA barcoding, COI

## New record of two species of the genus *Dendrothrips* (Thysanoptera: Thripidae: Dendrothripinae) from Korea

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Dendrothripine thrips are distinguished from other members of Thripidae by a remarkably elongate, “lyre-shaped” metasternal endofurca. This furca extends to the mesothorax as a pair of sinusoidal curved spurs, providing the insertion points for powerful muscles arising from the hind legs of the salatorial thrips. The subfamily Dendrothripinae, formerly known for a long time as the tribe Dendrothripini since Priesner (1925), was up-ranked to subfamily level of Thripidae by Bhatti (1989). Of the 97 species in 15 genera known worldwide, *Dendrothrips minowai* Priesner, 1935 and *Pseudodendrothrips mori* (Niwa, 1908) have been hitherto reported from Korea.

In this study of the Korean Dendrothripinae, two species of genus *Dendrothrips*, *D. ornatus* (Jablonowski, 1894) and *D. magnoliae* Kudo, 1984, are found for the first time. However, *D. minowai* Priesner recorded by Woo (1974), is excluded from the Korean fauna because of misidentification as supposed by Kudo (1984). Morphological characters for identification of three species including *P. mori* previously recorded are described and figured with a key to Korean species of Dendrothripinae.

**Key words:** *Dendrothrips*, *Pseudodendrothrips*, Dendrothripinae, Thripidae, Korea

P024

**First record of the genus *Yezoceryx*  
(Hymenoptera: Ichneumonidae: Acaenitinae) from Korea  
with the description of two species**

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The subfamily Acaenitinae Foerster, 1869 is a small-sized group belonging to the family Ichneumonidae. It includes 250 species in 26 genera from Ethiopian, Oriental, and Palaeartic region. However, only 14 species of six genera, *Arotos*, *Coleocentrus*, *Jezarotes*, *Phaenolobus*, *Spilopteron* and *Yamatarotes* have been reported from Korea.

This subfamily can be easily recognized from other ichneumonids by the combination of the following characters: subgenital plate very elongate; tarsal claws with accessory tooth. Members of Acaenitinae are parasitoids of wood-boring Coleoptera, Hymenoptera and Lepidoptera. Among them, some of parasitoids of Cerambycidae are known as intermediate carrier of *Bursaphelenchus xylophilus* (Nematoda: Parasitaphelenchidae).

In this study of the Korean Acaenitinae, we found the genus *Yezoceryx* from Korea for the first time, including newly recorded two species, *Y. sp.1* and *Y. sp.2*. We provide description of the genus and two species with a key to the Korean genera of the subfamily Acaenitinae.

**Key words:** *Yezoceryx*, Acaenitinae, Ichneumonidae, Korea

## 한국산 물거미의 신종 가능성 진단

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물거미, *Argyroneta aquatica* (Clerck, 1757)는 거미류 중 유일하게 물속 생활로 진화된 보존생물학적으로 매우 중요한 종이다. 세계적으로 구북구지역에만 분포하며 1속 1종이 알려져 있다. 다만, 학자에 따라서 그 종의 상위분류군을 물거미과 (Argyronetidae) 또는 굴뚝거미과(Cybaeidae)로 취급하는 정도에서 이견이 있을 뿐이다. 국내에서는 1995년 서식처가 새롭게 발견되면서 천연기념물로 물거미 서식지가 지정되어 보존생물학적 지표종으로 가치가 부각된 바 있다. 최근 대두된 분자분류 기술을 통해 4개의 유전자 마커를 이용하여 *Argyroneta aquatica*의 기산지인 유럽산 물거미와 국내서식 물거미표본의 염기서열을 비교 분석하였다. 그 결과 각각 COI에서 10.7%, HistonH3에서 1.5%, 18S rRNA에서 0%, 28S rRNA에서 0.08%로 특히 종동정 지표로 이용되는 COI에서 명확한 차이를 보였으며, HistonH3에서도 중간 특이 경향을 나타냈을 뿐 아니라 28S rRNA에서도 3 InDel events를 보여주었다. 또한 거미류 91속 179종의 333개 COI 염기서열에 대한 Neighbor-joining 분석을 추가로 수행한 바, 한국산 물거미와 유럽산 물거미의 유전적 변이수준은 거미류 종들의 중간 변이수준으로 분지됨이 뚜렷이 입증되었다.

**검색어:** 거미목, 물거미과, 물거미, 유럽산, 한국산, 분자분류, 형태분류

P026

## Unexpected problem in Aphid DNA barcoding by universal primers

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DNA barcode (mitochondrial COI) has been widely attempted for species identification of many animal groups including aphids. In this study, we newly found a DNA barcoding problem in a case study of the grain aphid, *Sitobion avenae*. Unexpectedly, five *S. avenae* individuals showed considerable differences of, on average, 32.6% in the DNA sequences from other conspecific individuals. BLAST search revealed that the five sequences are similar to those of aphid parasitoids such as *Aphidius*, *Ephedrus*, and *Praon* spp. (Hymenoptera: Braconidae). Based on these results, we concluded that the universal primers used in aphid DNA barcodes can amplify barcode sequences from parasitoid species within host aphids.

**Key words:** *COI*, DNA barcode, universal primers, aphid, parasitoid

P027

## Taxonomic Review of the Korean Gomphidae (Insecta: Odonata) with a Key to Species

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Korean species of the dragonfly family Gomphidae are reviewed based on a comprehensive specimen examination. The family can be easily recognized by separated compound eyes, yellowish body color, and similar features of triangle cells on fore- and hindwings. Since a report of 4 Korean species (*Seiboldius japonicus*, *Gomphus melampus*, *G. postocularis*, *Gomphus* sp.) of the family by Doi (1932), 18 species belonging to 13 genera were recorded by Lee (2006).

In this study, we added 5 species and reviewed 23 species of Korean Gomphidae. Identification key and taxonomic remarks were provide: *Asiagomphus pryeri* is recorded for the first time in South Korea; 3 North Korean species in the genus *Davidius* are added; *Gomphus postocularis* is treated as subspecies *Shaogomphus postocularis epophthalmus*; larval stage of *Burmagomphus* KUa is identified as *Burmagomphus collaris*; *Ophiogomphus forficula* is the synonym of *O. obscurus* not *O. reductus*.

**Key words:** Gomphidae, Identification key, taxonomic review, Korea

## 줄무늬폭탄먼지벌레속(딱정벌레목: 딱정벌레과)의 1 미기록종 보고

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줄무늬폭탄먼지벌레속(Mastax)은 분류학적으로 폭탄먼지벌레아과(Brachininae), 폭탄먼지벌레족(Brachinini)에 속하며 세계적으로 50여종이 아시아와 아프리카에 걸쳐 분포하는 희소 분류군이다. 본 속의 종들은 소형이며, 일반적으로 빨간 체색과 딱지날개의 특이적인 줄무늬 문양을 지닌 아름다운 색체를 띠고 있다. 국내에서 최근 줄무늬폭탄먼지벌레, *Mastax thermarum egorovi* (Lafer, 1973), 1종만이 보고된 바 있다. 이에 추가적으로 2009년도 충북 청원지역에서 채집된 표본에 대한 검토 결과, *Mastax formosana* Dupuis, 1912로 확인되었다. 이에 따라서 전자현미경적 미세구조 등 형태적 특징을 보고하고자 한다.

Family Carabidae 딱정벌레과

Subfamily Brachininae 폭탄먼지벌레아과

Tribe Brachinini 폭탄먼지벌레족

Genus *Mastax* Fischer von Waldheim, 1828 줄무늬폭탄먼지벌레속(신칭)

*Mastax thermarum egorovi* Lafer, 1973 줄무늬폭탄먼지벌레

*Mastax formosana* Dupuis, 1912 발줄무늬폭탄먼지벌레(신칭)

**검색어:** 딱정벌레목, 딱정벌레과, 줄무늬폭탄먼지벌레속, 미기록종



P029

## Redescriptions of Two Closely Resembling *Linnaemya* Species (Insecta: Diptera: Tachinidae) New to Korea

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In the process of revising the tachinid genus *Linnaemya* Robineau-Desvoidy in Korea, we have discovered two species for the first time in Korea. They closely resemble each other and need to be identified with caution. We here provide detailed redescrptions and illustrations with their diagnostic characters indicated. *L. atriventris* can be distinguished from *L. hirtipennis* by the combination of the following characteristics: 1) abdomen black in ground color; 2) wing vein R<sub>1</sub> without setulose; 3) hypandrium without secondary posterior lobe; 4) male with antero-basal 1/3 of flagellomere I distinctly swollen; and 5) postgonite very weakly curved dorsally.

**Key words:** Taxonomy, Diptera, Tachinidae, Linnaemyiini, *Linnaemya*, Korea

P030

## A new species of *Prorops* Waterston (Hymenoptera: Bethylidae) from the Cambodian Rain Forest

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*Prorops* Waterston is a small genus of the family Bethylidae (Hymenoptera) with just four species known worldwide: *P. nasuta* Waterston (cosmopolitan), *P. petila* Evans (Nearctic, Neotropical); *P. obsoleta* Evans (Neotropical); *P. rakan* Terayama (Palearctic).

A new species is recognized from the tropic rain forest of Cambodia. It is characterized from congeneric species by ‘the elongated median process on the lower part of frons and the flat-broad mandible downwardly developed’. The new species is described and illustrated with a key to world species of the genus *Prorops*.

**Key words:** Bethylidae, Cambodia, new species, Oriental region, *Prorops*

P031

## Species of the genus *Eurydema* (Hemiptera: Heteroptera: Pentatomidae) in Far East Asia: An integrated approach using morphological, molecular, and data crossing analyses for taxonomy

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In a revision of four *Eurydema* species recorded in Far East Asia, we confirm only two species, one of which consists of two subspecies: *E. dominulus* (Scopoli 1763) [= *E. pulchra* (Westwood 1837), **syn. nov.**], *E. gebleri gebleri* Kolenati 1846, and *E. gebleri rugosa* Motschulsky 1861 [**stat. nov.**]. In order to prove the above taxonomic changes, we compared three major characters; (1) the color patterns, (2) the mitochondrial COI (DNA barcoding) and (3) cross-breeding fertility (inter-specific copulation).

Two subspecies, *E. g. rugosa* and *E. g. gebleri*, preserve their own unique coloration patterns, confirmed by the intra-subspecific copulation and breeding. Interestingly, the 1<sup>st</sup> progeny from the inter-subspecific copulation of *E. g. rugosa*♂ X *E. g. gebleri*♀ (or *E. g. gebleri*♂ X *E. g. rugosa*♀) take the coloration patterns inherited from *E. g. gebleri*.

**Key words:** *Eurydema*; taxonomy; cross-breeding; DNA barcoding; Far East Asia

P032

## Recent Invasion of two North American aphids into Korea: *Illinoia* spp. (Hemiptera: Aphididae)

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The genus *Illinoia* is originally distributing in North America, few species found in other continents as exotics with the introduction of their hosts as ornamental plants and weeds. Recently, we confirmed two *Illinoia* species in Korea as the first record of this genus in the Eastern Part of Palaearctic: *Illinoia goldamaryae* (Knowlton 1938) on *Erigeron* sp. (Asteraceae) and *I. liriodendri* (Monell 1879) on *Liriodendron tulipifera* (Magnoliaceae). Two exotic aphids are illustrated, diagnosed, and discussed for their host plants, distribution, etc.

**Key words:** *Illinoia*, Exotic, New record, Aphididae, Korea.

P033

## Taxonomic Review of the Tribe Dendrometrini Gistel, 1856 (Coleoptera: Elateridae) in Korea

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We reviewed the Korean species belonging to the Tribe Dendrometrini. Of the previous Korean records, *Athousius humeralis* (Miwa, 1927) and *Limoniscus rufipennis* (Lewis, 1984) are confirmed as the misidentification of *Ampedus basalis* (Mennerheim, 1852) and *Corymbitodes* sp. recorded by Kishii and Paik (2002), respectively, and, in addition, the records of *Limonius eximus* (Lewis, 1874) and *Limoniscus vittatus* (Candeze, 1873) are also questionable since no specimens available in this study. A new species *Cidnopus* sp. nov. and a new record of *Cidnopus koltzei* (Reitter, 1895) is recognized in Korea. *Limonius scutellaris* (Dolin, 2003) comb. nov. is newly proposed.

Tribe Dendrometrini Gistel, 1856

*Athousiu humeralis* (Miwa, 1927) - misidentification

*Cidnopus* sp. nov.

*Cidnopus koltzei* (Reitter, 1895) - new to Korea

*Limonius eximus* (Lewis, 1894) - Korean specimen unavailable

*Limonius scutellaris* (Dolin, 2003) comb. nov. - new to Korea

*Limoniscus kraatzi kraatzi* (Candèze, 1879)

*Limoniscus vittatus* ((Candèze, 1873) - Korean specimen unavailable

*Limoniscus rufipennis* (Lewis, 1894) -misidentification

**Key words:** Coleoptera, Elateridae, Dendrometrini, taxonomy, Korea.

P034

## Weakness in Temperature Resistance of *Bemisia tabaci* by the Acquisition of Tomato Yellow Leaf Curl Virus (TYLCV)

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The sweetpotato whitefly, *Bemisia tabaci*, is a vector of more than 100 plant-diseased viruses as well as a serious pest to various horticultural crops. Virus acquisition affects the vector's development and reproduction, but its mechanism is largely unknown. Here we compared the temperature responses between non-viruliferous and TYLCV-viruliferous Q biotype of *B. tabaci*. When both non-viruliferous and viruliferous whiteflies were exposed for 1 and 3 h at 4, 25, and 35°C, the mortality rate of viruliferous whiteflies is higher than non-viruliferous after exposure at 4°C and 35°C, but no differences at 25°C between them. Analysis of the expression levels of heat shock protein (hsp) genes using the quantitative realtime PCR showed that viruliferous whiteflies has higher expression in hsp70, and hsp90 at both 4°C and 35°C, but no differences at 25°C. The results suggest that vector insects may not be durable to unfavorable temperature conditions when they acquire plant viruses.

**Key words:** hsp40, hsp70, hsp90, *Bemisia tabaci*, whitefly

P035

## The effects of ambient temperature on food selection, nutrient utilization, and performance in a generalist caterpillar, *Spodoptera litura*

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Temperature and nutrition are the two most important environmental factors influencing growth and survival in immature insects. There is ample evidence of interactions between these two factors but still little is known how changes in thermal environment affect feeding and nutrient utilization insect ectotherms. The aim of this study is to investigate the potential effects of ambient temperature on food selection and post-ingestive nutritional physiology in a generalist-feeding caterpillar of *Spodoptera litura*. Two separate experiments were performed. The first was a food choice experiment in which caterpillars were maintained through their final larval stadium under one of three constant temperatures (20, 25, 30°C) and given a choice between two nutritionally unbalanced diets that differed in protein (p) and carbohydrate (c) content (p42:c0 vs p7:c35 and p35:c7 vs p7:c35). In the second experiment, caterpillars were kept at the same thermal conditions as the first experiment but received a single diet from three no-choice feeding treatments (p35:c7, p21:c21 and p7:c35). When raised at the highest temperature (30°C), caterpillars from the choice experiment selected significantly more carbohydrate than those on lower temperatures whereas protein intake did not differ significantly between caterpillars across three test temperatures. Results from the no-choice experiment showed that lipid storage efficiency was reduced when caterpillars were maintained at the highest temperature (30°C). In both experiments, growth rate increased progressively with rising temperature. However, there was a significant temperature-by-diet interaction, with growth rates increasing more rapidly on p21:c21 diet than on the other diets (p35:c7 and p7:c35). Our results demonstrate that caterpillars adjust their nutrient preference to meet the increased energetic demand at high ambient temperature.

**Key words:** Carbohydrate; Food intake; Protein; Nutrient preference; Temperature

P036

## The Relationship between Endosymbiont Densities of *Bemisia tabaci* and the Transmission of Tomato Yellow Leaf Curl Virus (TYLCV)

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The sweetpotato whitefly, *Bemisia tabaci*, acts as a vector of more than 100 plant viruses. *B. tabaci* is known to harbor a primary endosymbiont (*Portiera*) and 6 secondary endosymbionts (*Arsenophonus*, *Cardinium*, *Fritschea*, *Hamiltonella*, *Rickettsia* and *Wolbachia*). These endosymbionts play important roles in the acquisition and transmission of plant viruses. Using PCR analysis, we identified endosymbiotic bacteria in various *B. tabaci* populations collected from different places of Korea. Distribution of endosymbionts was different according to the biotype of *B. tabaci*. Subsequently, their relative densities of endosymbionts were compared between TYLCV-viruliferous and non-viruliferous populations of the Q biotype using quantitative realtime PCR. We found that the densities of *Portiera*, *Cardinium* and *Hamiltonella* are higher in viruliferous than non-viruliferous whiteflies. Our results suggest the role of endosymbiont for the TYLCV transmission of whiteflies.

**Key words:** *Bemisia tabaci*, Endosymbiont, TYLCV, Whitefly



P037

## The Potential of *Drosophila* TRP Channels As Targets of Naturally Occurring Mosquito Repellent Cinnamaldehyde

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Cinnamaldehyde as the main component of *Cinnamomum* plants is well known as mammalian transient receptor potential ankyrin 1 (TRPA1) agonist, also activated by low temperature stimuli and mechanosensation. The other TRP subfamily, transient receptor potential vanilloid-1 (TRPV1) sensitive to pungent compounds such as capsaicin and allicin mediates the feeling of warmth. Both TRPA1 and TRPV1 channels are abundantly distributed in sensory neurons. Thus, there is possibility that these channels modulate repellent behaviors of mosquitoes and *Drosophila* through olfactory receptor neurons (ORNs). In order to confirm this hypothesis, we carried out laboratory repellent tests with cinnamaldehyde to *Aedes aegypti* females using arm-in-cage test and to a wild type and two TRP channel mutants *Drosophila* lines using a choice assay. Cinnamaldehyde showed strong repellency against *Ae. aegypti* and *Drosophila* wild adults at tested concentrations. However, a mutant fly line did not discriminate or detect the existence of the repellent. These behavioral data suggest that cinnamaldehyde may directly target the TRP channel. More studies to elucidate neural correlates of repellency to cinnamaldehyde compound are as follows: 1) Identifying the ORNs mediating cinnamaldehyde detection using single-sensillum recording techniques, 2) Co-localization of TRP genes on olfactory organs of *Ae. aegypti* and *Drosophila* using in situ hybridization and 3) Whether the *Aedes* TRP homologs might function in cinnamaldehyde repellency using rescued TRP channels of *Drosophila*.

**Key words:** *Aedes aegypti*, *Drosophila*, Cinnamaldehyde, TRP channels, Repellency

P038

## Synthesis of Insect Pheromone: (Z)-3-dodecenyl acetate

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Monoalkenyl acetates are used as one of lepidopteran pheromone components. However, (Z)-3-alkenylacetate as pheromone components is rarely known. Among them, (Z)-3-dodecenylacetate is used as pheromone components of *Protaetia anthonomae* and *Tecia solanivora*. Recently, (Z)-3-dodecenylacetate was identified as one of pheromone components for an insect pest in Korea (unpublished data). For the demand of development of mating disruption against the pest, large amount of (Z)-3-dodecenylacetate (Z3-C12Ac) was needed. Here, we reported the synthetic procedures for (Z)-3-dodecenylacetate (Z3-C12Ac).

The Grignard reagent from 1-decyne and ethyl magnesium bromide was reacted with ethylene oxide in dry tetrahydrofuran (THF). Thus synthesized 3-dodecyn-1-ol was reduced to (Z)-3-dodecen-1-ol (Z3-C12OH) by hydrogenation over Lindlar's catalyst. The alcohol was acetylated to desired (Z)-3-dodecenylacetate (Z3-12Ac) with acetic anhydride by general procedures. The yield was 62.6% through the all procedures. The purity was 98.0% (by GC-MS). The isomeric purity was >99% (by NMR).

**Key words:** Pheromone, (Z)-3-dodecenyl acetate, Moth

P039

## Mate choice test with eye color mutant of the brown planthopper, *Nilaparvata lugens* Stål

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In the previous study, we found an orange-eyed mutant of the brown planthopper (BPH). And we confirmed that its orange phenotype is controlled by single recessive allele in the autosome. To understand the effect of the orange eye color on mating of BPH, we designed two different combinations of the mate choice test with three virgin female and male BPH adults. The one consisted of orange-eyed female (org/org), orange-eyed male (org/org), and homozygous normal-eyed male (+/+) (female mate choice). The other was composed of orange-eyed male (org/org), orange-eyed female (org/org), and homozygous normal-eyed female (+/+) (male mate choice). In female mate choice test, four mating types could be distinguished according to the distribution of the eye-color phenotype in F1 progeny and their hatching-order in each mating pair. Two mating types showed only one eye-color phenotype, normal and orange, respectively, and the other two produced both eye-color phenotypes in a different hatching-order. In male mate choice test, both phenotypes of offsprings were also produced in most mating pairs. From these results, the effect of eye color on mating of BPH was not clearly found, but the multiple mating in both sexes and the mating preference by female are cautiously suggested.

**Key words:** *Nilaparvata lugens*, mate choice test, orange-eyed mutant, multiple mating, mating preference

## Temperature Effect on the Initial Diapause of the Ussur Brown Katydid, *Paratlanticus ussuriensis*, Eggs and Activation of Hsp Genes

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*Paratlanticus ussuriensis* enter prolonged diapause at an egg stage. Environmental conditions, such as temperature, can modify the diapause duration at initial diapause. Eggs enter initial diapause at 20°C, but continued early embryonic development at 30°C. Final diapause at a fully developed embryonic stage is obligatory regardless of temperature conditions. To determine temperature effects on diapause mechanism of *P. ussuriensis* eggs, we compared weights, DNA and RNA amounts of eggs incubated at either 20°C or 30°C for 50 days after oviposition. Both egg weight and total amount of DNA were constant at 20°C but gradually increased at 30°C. However, total RNA level was rapidly increased at 15 days-old eggs at 30°C and maintained high levels during further period whereas its level was constant at 20°C. In addition, we identified three heat shock protein 70 (*hsp70a*, *hsp70b*, *hsp70c*) genes of *P. ussuriensis* and determined those expression levels at different temperature conditions. The levels of *hsp70a* and *hsp70b* was not detectable until 20 days after oviposition at both temperature conditions, but highly increased at 50 and 60 days when incubated at 30°C. In contrast, *hsp70c* level was rapidly peaked at 20 days after oviposition, which is the time of initial diapause entrance. Our results suggest that high temperature breakdown initial diapause and a certain *hsp* gene, such as *hsp70c*, may involve in the initial diapause mechanism of *P. ussuriensis* eggs.

**Key words:** Egg diapause, Heat shock protein, *Paratlanticus ussuriensis*, Ussur brown katydid

P041

## 채집 시기 별 애멸구(*Laodelphax striatellus*: Delphacidae) 지역 계통의 약제 감수성 분석

민수정, 박창규, 이상계, 이관석, 김광호, 이시우

국립농업과학원 작물보호과

이동성 애멸구와 국내 월동 애멸구 개체군과의 약제에 대한 저항성 발현 특성 차이를 알아보기 위해 전국에서 이른 봄 2월에서 3월에 걸쳐 애멸구월동 개체군을 채집하였으며(월동계통), 같은 지역을 중심으로 8월과 9월에 걸쳐 애멸구를 논에서 채집하였다(본답계통). 각 계통 별 애멸구의 약제에 대한 반응 특성은 멸구류 방제에 사용되는 10개의 약제 (carbofuran, carbosulfan, ethofenprox, thiamethoxam, diazinon, dinotefuran, BPMC, fipronil, clothianidin, imidacloprid)를 선발하여, 채집된 애멸구를 실내에서 사육하여 충분한 개체수를 확보 후, 미량국소처리법으로 선발 약제에 대한 감수성을 조사, 결과를 분석하여 파악하였다. 월동 계통과 본답 계통을 약제에 대한 감수성으로 Paired t-test를 실시한 결과 밀양 계통은 통계적으로도 유의하게 월동 계통이 본답 계통에 비해 약제에 대한 감수성이 낮았다. 일반적으로 본답에서 채집한 계통이 월동계통에 비해 시험 약제에 대해 높은 감수성을 보였다. 시험 약제 각각에 대한 두 계통 간 비교에서 본답 계통은 carbofuran, BPMC, imidacloprid에 대해 높은 감수성을 보였으며, 월동 계통은 carbosulfan, ethofenprox, diazinon, fipronil에 대해 높은 감수성을 보였다. 그러나 두 계통의 약제 감수성 차이는 통계적 유의하지는 않았다. dinotefuran, clothianidin, fipronil은 지역 간에 전혀 차이가 없었다.

**검색어:** 애멸구, *Laodelphax striatellus*, 약제 감수성, 월동계통, 본답계통

P042

## Age-dependent Olfactory Dysfunction in a Neurodegenerative Disease Fruit Fly Model

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Alzheimer's disease (AD) is a fatal disorder wherein patients suffer from sensory, motor, and cognitive loss. Currently, the identification and validation of biomarkers for diagnosing AD and other forms of dementia are increasingly important. Olfactory dysfunction is present in patients diagnosed with Alzheimer's disease or idiopathic Parkinson's disease. Alzheimer's patients show neuropathological changes in areas of the brain central to the olfactory processing center, suggesting the theoretical importance and potential diagnostic utility of investigating functional changes in olfaction in these patients. However, the usefulness of olfactory screens to serve as informative indicators of Alzheimer's is precluded by the lack of knowledge regarding neural and molecular mechanisms underlying olfactory dysfunction onto Alzheimer's diseases. To test these ultimate questions, we used molecular and electrophysiological recording techniques to find out the difference of olfactory responses and AD related protein expression patterns by using fly model, *Drosophila melanogaster* that over-expresses the human  $\beta$ -amyloid, tau protein. We postulated that such flies would present with progressive olfactory impairments compared with age-matched wild type control flies. In this study, our hypothesis is that there is a correlation between olfactory deficits and the spatial expression pattern of  $\beta$ -amyloid and tau protein deposition. Therefore, we demonstrate a specific concentration of lesions in central olfactory structures such as antenna and Maxillary palps. Our study indicates that deficits on olfactory identification may occur in AD, which will be valuable as an indicator of neuropathogenesis.

**Key words:** Alzheimer's disease,  $\beta$ -amyloid, tau protein, olfactory dysfunction

## 팔나방과 어리팔나방 사이의 불명료한 생식격리

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팔나방(*Matsumuraeses phaseoli*)과 어리팔나방(*M. falcana*)은 외부 형태로 쉽게 구분할 수 없으나, 수컷 생식기 형태와 미토콘드리아 시토크롬 옥시다제 I 유전자 염기서열에서의 차이가 보고되어 왔다. 또 두 종이 성페로몬으로 3개의 화합물을 같이 사용하고 있으나, 그 조성은 서로 다른 것으로 보고되었다. 그러나 각 종에 대해 밝혀진 조성으로 제작된 합성 성페로몬 미끼를 이용하여, 야외에서 각 종을 트랩에 유인하고, 포획된 수컷들의 생식기 형태와 미토콘드리아 옥시다제 I 유전자 표지로 종을 구분한 결과는, 각 곤충종의 트랩에 두 종이 동시에 유인되는 것을 보였다. 이 결과는 한편으로 성페로몬 조성이 각 종에 대해 완벽하게 밝혀지지 않았을 가능성과, 다른 한편으로 야외에서 이들 두 종이 생식적으로 완전하게 분리되어 있지 않았을 가능성을 나타내었다. 또 두 종의 교잡실험에서도 후대 세대가 생성될 수도 있음을 보였다. 따라서 본 연구에서는 각 종의 짝짓기 통신에 절대적인 특이성이 있는가를 관찰하기 위해 처녀 암컷을 미끼로 이용하여 수컷을 포획하는 시도를 하였다. 결과에서 어리팔나방 암컷 트랩에 잡힌 수컷들의 대부분은 어리팔나방이었는데, 팔나방 암컷 트랩에 잡힌 수컷들에서는 팔나방 보다는 어리팔나방의 수가 더 많았다. 미끼를 설치하지 않은 트랩에는 두 종 모두 포획되지 않아, 이 결과가 우연한 것이 아님을 보였는데, 결국 이 결과로 두 종 사이에 생식 격리 메커니즘이 완벽하게 작동하고 있지 않다고 추정하였다.

**검색어:** 팔나방, 어리팔나방, 생식격리, 암컷 트랩, 수컷 유인

P044

**Annual patterns of occurrence of *Riptortus pedestris* (Hemiptera: Alydidae) and its egg parasitism in a field where a series of crops cultivated**

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From our previous studies in a farm in Songcheon, Andong where a series of crops was cultivated in 2008 and 2009, occurrence patterns of *Riptortus pedestris* (Fabricius) (Hemiptera: Alydidae) and its egg parasitism by *Ooencyrtus nezarae* Ishii (Hymenoptera: Encyrtidae) and *Gryon japonicum* (Ashmead) (Hymenoptera: Scelionidae) were reported. With an objective to verify the trend of the occurrence pattern, a year long monitoring of *R. pedestris* and its egg parasitism was continued in 2010 in the same location where barley, sesame, and soybean were cultivated in series. We placed four aggregation pheromone traps added with 50 refrigerated eggs of *R. pedestris* each along the perimeter of the field from 11 April to 31 October. Weekly occurrence patterns of *R. pedestris* and its parasitism in 2010 were generally similar to the patterns of previous years. *Riptortus pedestris* population first appeared in the last week of April, peaked after the third week of August, and declined in October. Parasitism by *G. japonicum* was recorded up to 64% in July, 2010 which was much higher than previous years. This study verifies that *G. japonicum* is the first colonizer that appears as early as May and remains active until September. *Ooencyrtus nezarae*, however, starts to occur late from the last week of August and exist in the field until October.

**Key words:** *Gryon japonicum*, *Ooencyrtus nezarae*, soybean, stink bug, parasitoid, phenology



P045

## Temporal pattern of apple borers infestation and escape in late season

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Apple borers such as oriental fruit moth (OFM) *Grapholita molesta* (Busck) (Lepidoptera: Tortricidae), and peach fruit moth *Carposina sasakii* Matsumura (Lepidoptera: Carposinidae) can reduce the yield and its quality if not managed properly. Even peach fruit moth infestation in harvested apple could produce quarantine problem in exportation. We investigated the temporal distribution of apple borers infestation in an apple orchard where the infestation level of fruit was around 95% from September to early December, 2010. Every week, 150 apples were harvested from the apple orchard in Giran, Andong, Korea and 50 apples were cut to monitor the number of larval infestation. At the same time another 100 apples were kept in plastic container inside and outside the laboratory 50 each to check the escape of the infested larvae for overwintering cocoon formation. All larvae collected were identified based on the morphology and also verified by DNA sequence. The study indicates that the numbers of the infested larvae increased from September to October second week and then slightly decreased until early December with similar number of holes per apple. The holes produced by the escaping larvae were mostly found on dorsal side of the apple, but less on basal portion. Most of the infested larvae escaped from apple during late October to early November. Based on morphological characters such as anal comb, crocket and pupation shelter, the collected larvae were identified. 42.31% of larvae were *G.molesta*, 52.59% of larvae were *C.sasakii* and 5.10% were other species not identified.

**Key words:** *Grapholita molesta*, *Carposina sasakii*. Temporal distribution, holes, overwintering, morphological characters

P046

**Accessing phosphoglucose isomerase (*pgi*): a gene with potential links to fitness and invasibility of the leafroller *Epiphyas postvittana* (Lepidoptera)**

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Light brown apple moth, *Epiphyas postvittana*, is a significant horticultural pest native to Australia, and currently with a limited global distribution. However it can tolerate very heterogeneous climatic and vegetation conditions and has recently invaded California with considerable consequences for US international and domestic trade. A genetic factor that may contribute to its environmental adaptability, and consequently invasive capability, is the phosphoglucose isomerase gene (*pgi*). This gene codes for a key enzyme in the second step of glycolysis and for which the isozyme composition has been associated with the fitness and dispersal capacity of other moths. As a first step, to determine if this locus is variable within *E. postvittana*, novel primers were designed enabling access to 957 bp of the coding region across exons 4 to 11 of *pgi*. Exon-primed intron-crossing (EPIC) primers were then designed to compare sequences of 17 specimens across one laboratory and three wild New Zealand populations from a latitudinal range of ~39-45°S. A total of 70 segregating sites in the exons were found, including 61 synonymous and nine nonsynonymous. Introns 3 to 11 (excluding intron 10) were also sequenced for 13 individuals revealing significant length variation within and between introns and populations. The level of variation revealed here indicates that this could be a useful target gene to assess fitness factors associated with invasibility of *E. postvittana*.

**Key words:** biosecurity, exotic species, invasive species, quarantine pest

P047

## Mathematical models applied to dispersal data of pest populations in greenhouse

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In order to achieve the optimized pest control, correct estimation of pest densities is a prerequisite to monitor pest damage and to provide efficient pest management plans. Parameters regarding diffusion (e.g., diffusion constant) and population size (e.g., growth rate) were estimated by using diffusion equation. The time series dispersal data of Whiteflies collected in greenhouse were used for modeling. Cross-correlation analysis was conducted to reveal the range and direction of pest population invasion. Sampling theory was further investigated regarding estimation of densities, and population dynamics of Whiteflies were discussed in two dimensions.

**Key words:** Dispersal, Diffusion equation, Cross-correlation analysis, Whitefly

## Modeling applied to drifting in aquatic insects

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Stream and river habitats are characterized by a uni-directional water flow. Organisms colonizing such habitats are faced with the constraint of continuous downstream flow. Some ecologists find it puzzling that upstream is colonized by insect communities although the insects are continuously faced with downstream flow. The obvious solution to the puzzle is that there exist compensatory strategies, three of which have gained some notoriety in recent years: 1) diffusive random movement and density-dependent regulation of population size; 2) daily directed movement during larvae stage; 3) the compensation of larval drift by adult upstream flight. We have adapted an eco-evolutionary individual-based model (IBM) to accommodate typical life events of aquatic insects, such as birth, death, diffusion, and drifting. The probabilities of these events, which occur on the individual level, depend on both biological (e.g., local competition, upstream flight by adult insects) and environmental (e.g., unidirectional flow) constraints. The evolution of selected traits, namely, adapted water velocity, drifting time and distance, and upward flight distance, was investigated through simulation. We find that, while the three strategies are generally able to sustain upstream populations, the exact compensation of drift loss allowed by upstream flight makes the third strategy less “asteful” a population of upstream flight strategists to outcompete diffusive movement strategists. We also report branching of adapted traits in drifting during the course of evolution. Individuals with high current velocity preferences either spend short (several seconds) or long (an hour) duration in water flow, while the individuals with low current-velocity preference only spend middle range (half an hour) of duration in water flow.

**Key words:** Drift paradox, individual-based model, aquatic insects, speciation

## 무당벌레(*Harmonia axyridis*) 장내세균이 기주의 생물학적 특성에 미치는 영향

강동균, 길영중, 김기수, 곽창순, 서미자, 윤영남, 유용만

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곤충의 생태학적 역할에 있어서 공생미생물은 대부분의 곤충그룹에서 나타나는 상호간 절대적 이익관계에서부터 해로운 기생적 관계까지 여러 다양성을 가지고 있다. 곤충의 장내에서나 표면에서 많은 다른 미생물들과 서로 다양한 방법으로 공존하면서 생활하고 있는데, 넓은 범위에서 공생관계가 있는가 하면 기주의 생리에 아주 밀접하면서 필수적인 관계만을 나타내는 것도 있다. 공생자는 대부분 곤충의 소화기관 부근에서 발견되어지고, 이것은 성장과 발육에 필수적인 아미노산이나 비타민 등을 합성하는 것으로 밝혀지고 있다. 본 연구에서는 포식성 곤충인 무당벌레(*Harmonia axyridis*)의 령기벌, 먹이별로 장내에 존재하고 있는 세균의 분리 및 동정을 통해, 무당벌레 장내미생물의 종류를 알아보고 무당벌레의 생물학적 특성에 미치는 영향을 보고자하였다.

충남 금산의 월동개체군을 채집하여 무테두리진딧물로 실내에서 누대사육을 통해 확보한 자손세대 무당벌레 유충(1령~4령)과 진딧물, 설탕물, 닭간을 먹인 성충의 소화기관을 분리하고 장내세균을 분리 동정한 결과, 총 31균주가 분리 동정되었다. 설탕물을 먹인 성충을 제외하고 모든 령기와 성충에서 *Staphylococcus saprophyticus*가 분리 동정되어, 이 세균을 실험균주로 선발하여 *S. saprophyticus*의 존재여부에 따른 기주곤충의 발육특성 및 생식특성에 미치는 영향을 조사하였다. 대상균주의 부재로 인한 특성을 확인하기 위해 항생제인 ofloxacin을 처리한 처리구와, *S. saprophyticus*을 먹이인 진딧물에 처리하여 공급한 후, 무당벌레의 산란력, 부화율, 번데기 무게, 유충발육기간을 조사한 결과, 알의 부화율은 항생제 처리로 인한 실험 장내세균의 부재로 인해 감소하는 경향을 보였으나, 유충의 발육기간이나 번데기 무게와 같은 발육특성에 미치는 영향은 확인되지 않았다.

검색어: 무당벌레, 장내세균, *Staphylococcus saprophyticus*

## Geographic Homogeneity and High Gene Flow of the Pear Psylla, *Cacopsylla pyricola* Foerster (Homoptera: Psyllidae), Detected by Mitochondrial COI Gene and Nuclear Ribosomal Internal Transcribed Sequence 2

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The pear psylla, *Cacopsylla pyricola* Foerster (Homoptera: Psyllidae), is a serious insect pest of commercial pear crops. The species, which resides on pear trees throughout its life cycle, is rapidly spreading in some regions of the world. Given the life cycle, it is unclear how such a rapid spread has been facilitated. Presently, the population genetic structure of the species including genetic diversity and gene flow was studied to understand the nature of dispersal and field ecology of the species. Pear psylla was collected from several pear orchards in Korea. The 658-bp region of mitochondrial COI gene and the 716-bp long complete internal transcribed spacer 2 (ITS2) of the nuclear ribosomal DNA were sequenced. Unlike other previously studied insect pests, the COI-based genetic diversity of the pear psylla was extremely low (maximum sequence divergence of 0.15%). This finding allowed us to conclude that the species may have been introduced in Korea relatively recently, possibly with the phenomenon of genetic bottlenecks. ITS2 sequence-based analyses of phylogeny, population differentiation, gene flow, and hierarchical population structure all concordantly suggested that the pear psylla populations in Korea are neither genetically isolated nor hampered for gene flow. These genetic data are concordant with the dispersal of an overwintering winterform morph outside the non-pear habitat in the fall and the possibility of subsequently longer distant dispersal.

**Key words:** *Cacopsylla pyricola*, mitochondrial COI gene, ITS2

P051

## 블루베리에서 블루베리혹파리(가칭) (*Dasineura oxycoccana*) 발생 및 피해 특징

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최근 전국적으로 블루베리 재배면적이 증가하면서 관련 병해충들이 증가하고 있는 실정이다. 2010년부터 블루베리에 발생하는 해충들을 조사하면서 일부 비가림 재배지를 중심으로 블루베리 나무 순에 원인불명 피해가 확인되었고(80% 이상), 일부 순끝 시드는 부위에서 1~2mm 전후의 혹파리 유충들이 발견되었다. 피해 발생농가에서 혹파리 유충을 다수 채집하여 성충으로 우화시킨 다음 국립식물검역원에 동정을 의뢰결과 국내 미기록종인 블루베리혹파리(*D. oxycoccana*)로 동정되었다. 2011년 현재까지 조사 결과 이 해충은 겨우내 토양속 등에서 번데기로 월동하는 것으로 추정되고 있고, 재배 초기 블루베리에서 꽃눈과 신초부위에 알을 산란하여 가해하는 것으로 확인되었다. 2010년의 경우 경기 화성, 평택, 충북 청원, 경북 상주 등 대부분 포장의 블루베리에서 순 피해가 나타났는데, 특히 노지보다 시설내에서 피해가 심하였다. 블루베리혹파리 피해 증상은 새순이 흑변하며 말려 들어가므로 생리 장애와 유사하고 유충과 성충은 육안으로 관찰하기 힘들기 때문에 농가에서 진단이 어렵다. 위 해충 발생 초기 적절한 방제 수단을 강구하지 않을 경우 비가림 재배지를 중심으로 많은 피해를 유발할 수 있으므로 주의가 필요하다.

**검색어:** 블루베리, 블루베리혹파리, *Dasineura oxycoccana*, 혹파리과, 해충, Vaccinium

## Temperature-dependent developmental model of *Monochamus saltuarius* (Coleoptera: Cerambycidae)

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The developmental time and survival of overwintering larvae of *Monochamus saltuarius* were studied at 7 constant temperatures (16, 20, 23, 25, 27, 30, 34°C), and a photoperiod of 16 : 8 (L : D) h. The total mortality of overwintering *M. saltuarius* was lowest at 27°C (7%) and highest at 34°C (93%). The total developmental time decreased with increasing temperature between 16°C (49.48 days) and 34°C (13.00 days). The relationship between the developmental rate and temperature was fitted by five nonlinear developmental rate models (Logan 6, Lactin 1, 2 and Briere 1, 2). The nonlinear shape of temperature development was best described by the Briere 1 model ( $r^2=0.99$ ). The developmental variation of overwintering larvae was well described by the three-parameter Weibull distribution model ( $r^2=0.98$ ). The temperature-dependent developmental models of *M. saltuarius* developed in this study could be used to predict emergence period of the adult, or to develop a population dynamics model of *M. saltuarius*.

**Key words:** *Monochamus saltuarius*, developmental rate, nonlinear developmental rate model, temperature



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## Rearing method of Potato tuber moth, *Phthorimaea operculella* (Zeller), and its oviposition characteristics

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Potato tuber moth (PTM) has been a destructive pest on potato in the fields and stores through tropical to subtropical area. According to global warming, PTM distribution limit in Korea is facing north gradually. Recently, potato fields damaged by PTM are reported intermittently in the midsection of a country and southward. To secure a sufficient number of insect with equal growth stage is a prerequisite for investigating bionomics and developing new agrochemicals to control pests. In 2009, we collected PTM larvae first from the potato fields in Miryang and Gimcheon, and then placed them into transparent hexagonal rearing cage (30×30×30cm) with providing potato tubers as a food till emergence. A transparent cylindrical rearing cage (Φ15×30cm) erected vertically before putting emerged adults, and covered upper opening with net (50 mesh). To get eggs, we placed a filter paper (Φ11cm, called ‘oviposition paper’) on the net and sprinkled sugar solution. The oviposition paper laid eggs was stored in 10°C refrigerator and changed with new one every 1~2 day interval. The developmental period of eggs to hatch was 5.2±0.7 days at 23±2°C, L16/D8 condition. Although adults laid eggs continuously for two weeks, second to fifth days after emergence showed highest oviposition, which suggested the most efficient periods for collecting sufficient eggs. A hatchability of eggs laid within 10 days after emergence was over 90%.

**Key words:** *Phthorimaea operculella*, oviposition paper, rearing

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## Effectiveness of *Encarsia formosa* to control the greenhouse whitefly, *Trialeurodes vaporariorum* in tomato greenhouse

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Effectiveness of *Encarsia formosa* (Hymenoptera: Aphelinidae) to control *Trialeurodes vaporariorum* (Hemiptera: Aleyrodidae) was investigated in the commercial tomato greenhouse from January to June, 2010. Densities of *T. vaporariorum* were monitored using the yellow sticky trap for adult, and a lupe (x10) for 4th instar nymph and pupa at 1 week interval. Tomato seedlings were transplanted in mid-January and the nymph and adult of *T. vaporariorum* were first discovered in February 4th. *E. formosa* was applied as a mummy card at a recommended density (3 parasitoids per 1m<sup>2</sup>) at 2 weeks interval for 8 times. Mummy cards were collected 2 weeks later and the emergence and survival ratio of *E. formosa* were examined. Density of adult *T. vaporariorum* was significantly lower in the treatment plot (F=42.48,  $p=0.0001$ ). The control efficiency ranged from 57.3% to 88.5%. The nymphal density was also significantly lower in the treatment plot (F=8.85,  $p=0.0053$ ). The control efficiency was 84% on 25th March, 75% on 18th May and 95% on 25th May. Maximum 50% parasitism by *E. formosa* occurred in the treatment plot. The emergence and survival rates of *E. formosa* on mummy cardboards that were released in the greenhouse during February to March were only 53% and 41%, respectively. These rates increased to >70% as the temperature rises.

**Key words:** greenhouse whitefly, *Trialeurodes vaporariorum*, *Encarsia formosa*, tomato

## Geographic Genetic Contour of the Dung Beetle, *Copris tripartitus* (Coleoptera: Scarabaeidae), that Is Endangered in Korea

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The dung beetle, *Copris tripartitus*, (Coleoptera: Scarabaeidae), is one of the insect species listed as endangered wildlife in Korea. In order to establish conservation strategy an investigation on nation-wide genetic magnitude and nature of genetic diversity would be required. In this study, we sequenced each partial sequences of mitochondrial COI (658 bp) and CytB (433 bop) genes and complete internal transcribed spacer 2 (ITS2) of the nuclear ribosomal DNA (411~420 bp) from 70 individuals of *C. tripartitus* collected from five Korean localities. The sequence divergence of mitochondrial genes was unexpectedly substantial as 5.0% (33 bp) for COI and 4.6% (20 bp) for CytB, whereas that of ITS2 was only 1.9% (6 bp), revealing much higher variability in mitochondrial DNA. In phylogenetic analysis, each 57 and 47 haplotypes obtained from COI and CytB gene sequences was subdivided into two groups (groups A and B), but the node supports for each group was not strong enough to consider each group as independent monophyletic groups in both genes. This interpretation was further supported by the same analysis with ITS2, showing no subdivision at all. These findings reinforce importance for the inference of phylogenetic result using both mitochondrial and nuclear encoded sequences. The *C. tripartitus* occurring in Korean peninsula was genetically well connected to each other and no obvious population genetic structure was detectable.

**Key words:** *Copris tripartitus*, Endangered species, Geographic Genetic Contour

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## Ecotoxicological evaluation for contaminated abandoned mine soils using *Daphnia magna*

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Sedimentation of soil particles in water is perhaps the most significant pathway to contamination of aquatic ecosystems. In this scenario, the use of freshwater organisms for assessing sediment toxicity will be considered more ecologically relevant than tests that use aqueous soil extracts. To evaluate the toxicity of soils sampled in the vicinity of the abandoned mine located in the Gyeonggi province, *Daphnia magna* were exposed to a 1:4 of soil to water which soil samples were serially two-fold serially diluted with clean sand to concentrations ranging from 6.25 to 100 % % (w/w) for 24- and 48-h. Irrespective of exposure time, the survival of *D. magna* for reference soil was not decreased, while the survival of *D. magna* showed high sensitivity to the soils with moderate as well as high metal concentrations. Moreover, the heavy metal concentrations in the water samples increased with increasing the heavy metal concentrations in the soils, which indicates the increased sensitivity is the consequences of the bioavailable fraction of contaminants in soils. These results clearly showed that the freshwater organism *D. magna* can be used as test species to assess the potential impact of soil contaminants into aquatic ecosystems.

**Key words:** *Daphnia magna*, Whole-sediment toxicity test, Metal-contaminated mine soil

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## Development and characterization of ten polymorphic microsatellite markers in the seven-spotted lady beetle, *Coccinella septempunctata* (Coleoptera: Coccinellidae)

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The seven-spotted lady beetle, *Coccinella septempunctata* (Coleoptera: Coccinellidae) has a broad ecological range, living almost anywhere there are aphids for feeding. In this study, we isolated and characterized a total of 10 microsatellite loci from the species. The loci were validated and characterized using 25 samples collected from five Korean localities. The number of alleles and heterozygosity observed at each locus ranged from 4 to 16 and from 0.37 to 0.89, respectively. None of the loci deviated significantly from Hardy-Weinberg equilibrium and there was no indication of significant linkage disequilibrium among pairs of loci. These microsatellite markers should be very valuable markers for population genetic studies of *Coccinella septempunctata*.

**Key words:** *Coccinella septempunctata*, Coccinellidae, Coleoptera, Microsatellite

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## Geographic Genetic Contour of the Seven-Spotted Lady Beetle, *Coccinella septempunctata* (Coleoptera: Coccinellidae), on the Basis of Mitochondrial COI Gene and Nuclear ITS2 Sequences

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The seven-spotted lady beetle, *Coccinella septempunctata* (Coleoptera: Coccinellidae), known also as the seven-spot ladybird, is natural enemy for aphids and has a broad ecological range, living almost anywhere there are aphids for it to eat. In order to understand the genetic diversity and geographic variation of the species we sequenced a portion of mitochondrial COI gene (658 bp) and complete nuclear internal transcribed spacer 2 (ITS2) collected from nine Korean localities. A total of 21 haplotypes (CSCOI01 ~ CSCOI21), with the maximum sequence divergence of 4.56% (30 bp) were obtained from COI gene sequence (from 78 individuals), whereas 65 sequence types (CSITS201 ~ CSITS265), with the maximum sequence divergence of 2.06% (11 positions) were obtained from ITS2 (from 79 individuals), indicating substantially larger sequence divergence in mitochondrial gene sequence. Both COI gene and ITS2 shows the distribution pattern that only a few haplotypes or sequence types are widely distributed, whereas majority of them are highly restricted in one geographic location, even represented as a single individual. Unlikely the ITS2 sequence types the mitochondrial COI haplotypes evidenced the presence of two main phylogenetic groups, reciprocally monophyletic to each other. Geographically, these two groups are spread in all localities surveyed. Considering both COI gene and ITS2 sequence together, current our data may suggest the presence of ancestral polymorphism, rather than on-going speciation, but more scrutinized analysis will be performed soon. Due partially by the presence of both COI groups in all surveyed localities, the genetic diversity estimates of all localities are similar from the perspective of COI gene, but ITS data showed extremely lower genetic diversity of one islet locality, Anmyeon-do (locality 2; 0.002530 vs. 0.008054 ~ 0.012060). Analysis of gene flow estimates between localities indicates that most populations are highly interconnected to each other. However, one islet locality, Anmyeon-do (locality) has shown statistically significant distance from the remaining localities on the basis of only ITS2 data ( $F_{ST} = 0.19 \sim 0.34$ ), requiring scrutinized phylogeographic inference on this population with expanded sampling. As more scrutinized analysis is performed, further fruitful inference on the geographic contour of the species might be available.

**Key words:** *Coccinella septempunctata*, Mitochondrial DNA, COI gene, ITS2, DNA Polymorphism, Population genetic structure

## Three species of cockroaches collected from seven different habitats in Jejusi, Republic of Korea (ROK) from 2005 to 2006

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This study was carried out to investigate the inhabitation features of cockroaches in Jejusi, Korea. For sampling, fourteen sites were selected from every two sites of seven different habitat categories, including dwelling house, Korean restaurant, Japanese restaurant, Chinese restaurant, tea-room, hotel-inn and hospital. The cockroaches were weekly captured using sticky-traps from March, 2005 to February, 2006. Studies were focused on the temporal fluctuations of the total sample and two developmental stages (nymph and adult), the sex ratio, the positive trap percentage, and the comparative population sizes of the habitats. The positive trap percentage was 16.64%. Three species, *Blattella germanica*, *Periplaneta americana*, and *Periplaneta fuliginosa*, were confirmed to inhabit in Jejusi. The predominant species was *P. fuliginosa* (89.16%). Meanwhile, *P. americana* and *B. germanica* were shown to be much lower population size (6.44 and 4.40%, respectively). The mean sex ratio was 0.75% (males/females): *B. germanica*, 0.62%, *P. americana*, 0.29% and *P. fuliginosa*, 0.87%. The nymphs (82.19%) surpassed the adults (17.81%) in the individual number. *Periplaneta fuliginosa* also exceeded much more the other two species (*P. americana* and *B. germanica*, 5.37% and 1.67%, respectively) in the nymph number/the collected cockroaches. Both curves of the nymph and adult in the seasonal population change of *P. fuliginosa* made the peaks at September. This result suggested that the life cycle of this species is univoltine. The positive trap percentage and population size in the Japanese restaurant where was shown to be the most heavily polluted habitats by cockroaches were 20.67% and 0.79 (individuals/trap/week), respectively. Also, Chinese restaurant and dwelling house where were shown to be comparatively high polluted were 31.67% and 23.75% in positive trap percentage and 0.76 and 0.40 in population size, respectively. In contrast, hotel-inn, tea-room, hospital and korean restaurant were shown to be quite or very low numbers as 16.50%, 16.00%, 6.20%, and 6.00% in positive trap percentage, and 0.37, 0.18, 0.10, 0.06 in population size, respectively. It was concluded that there were differences in the species composition and the actual living conditions of the cockroach between Jejusi and other cities of Korea.

**Key words:** Cockroach, *Blattella germanica*, *Periplaneta fuliginosa*, *Periplaneta americana*, Jeju City, Republic of Korea (ROK)

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## 화살까지벌레 여름성충 온도별 산란 및 발육 특성

김수빈, 장용석, 강성혁, 현승용, 김용근, 김종현, 정대천<sup>1</sup>, 김동순

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화살까지벌레(*Unapsis yanonensis* Kuwana) 여름성충의 온도별 산란 및 발생 약충의 발육 특성을 구명하기 위하여 서귀포농업기술센터 시험포장에서 2010년 8월 감귤 잎에 발생한 성충을 채집하였다. 야외 채집한 성충은 5개 항온기에서 각 온도(13°C, 17°C, 25°C, 29°C, 33°C, 16L8D, RH 30~60%) 처리하여 관찰하였다. 화살까지벌레는 깍지 내에서 산란 및 부화하여 약충으로 발생하는 특성을 갖고 있어 잎에 발생한 약충수를 산란수로 조사하였다.

여름성충의 산란기간은 29°C에서 53.1일로 가장 길었으며, 17°C에서는 31.9일, 13°C에서는 33.9일로 조사되었고, 고온조건인 33°C에서 29.0일로 가장 짧았다. 산란 수는 13°C에서 46.5개로 가장 적었으며 저온에서 고온으로 갈수록 증가하여 29°C에서 254.5개로 조사되었으나 33°C에서는 128.1개로 오히려 감소하였다. 한 성충의 산란수는 주기에 따라 증가 및 감소하여 그 경향이 저온인 13°C에서 2회, 그 외 온도에서는 3회 관찰되었다. 1회로부터 마지막 주기까지 각 구간 산란수는 점차 감소하여 29°C의 경우 1회째에 123.2개, 2회째에 84.9개, 3회 이상에서 46.4개 산란하였다. 발생한 약충의 성비는 1:0.48(13°C), 1:4.85(17°C), 1:2.34(25°C), 1:1.85(29°C), 1:0.56(33°C)로 조사되었다.

온도별 발육실험 결과 약충은 13°C에서 1회 탈피 후 발육하지 못하였고 33°C에서 2회 탈피하였으나 성충으로 완전히 신장하지 못하였다. 성충까지의 발육기간은 17°C에서 108.1일, 29°C에서 46.4일, 25°C에서 44.4일이었다.

**검색어:** 화살까지벌레, 산란, 산란주기, 발육기간, 감귤



P061

## Ecotoxicological evaluation for contaminated abandoned mine soils using *Heterocypris incongruens*

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Soil contamination can be one path for stream and groundwater contamination. In this study, the toxicity of soils sampled in the vicinity of the abandoned mine located in the Gyeonggi province was evaluated using freshwater organisms *Heterocypris incongruens*. Two different exposure scenarios, one is in the aqueous only exposure, and the other is in the aqueous + soil exposure. The seven different soil samples were tested depending on the contamination level; reference (1 soil), moderately contaminated (4 soils) and highly contaminated (2 soils). In the toxicity tests, *H. incongruens* were exposed to water extracts (aqueous only exposure) and soils (aqueous + soil exposure) which were serially two-fold diluted with either EPA moderate hardwater or clean sand, respectively. After 6 days of exposure, no significant impact on the survival was found in the both systems for reference soil, while only significant impact was found in the aqueous + soil system for moderately contaminated soil. And the survival of *H. incongruens* was dramatically decreased with decreasing dilution series for highly contaminated soils. Interestingly, the toxicity of aqueous + soil system was higher than that of aqueous only system, implying the exposure of chemicals to *H. incongruens* may be a consequence of its foraging behavior onto the surface of sediment. From the results of this study, the freshwater organism *H. incongruens* can be used as surrogate test species to assess the soil contamination.

**Key words:** *Heterocypris incongruens*, mine, exposure systems

## 상주지역 배 과원에서 가루깍지벌레 (*Pseudococcus comstocki*)의 발생 동태

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관행관리와 친환경관리를 하는 경북 상주시 공검면 일대 10개의 배과원에서 2005년부터~2010년까지 6년간 가루깍지벌레의 발생 생태를 모니터링하였다. 가루깍지벌레는 난피로 가지틈 등에서 월동을 하는 데 알부화성기는 4월중~5월상순, 성충산란 최성기는 6월중~하순, 2세대 알 부화시기는 6월하순~7월상순으로 예측된다. 과원별 연간 누적발생량은 2마리/지점/년에서 49.8마리/지점/년으로 최근 급격히 밀도가 높아지는 추세이며, 과원별 변이계수 역시 168%에서 48%로 꾸준히 줄어드는 추세이다. 과원 관리 형태별로 보면 친환경재배농원, 무관리재배농원, 일반관행재배관리농원, GAP 농원순으로 약제 관리가 적게 들어가는 과원에서 발생이 더 많아지는 것으로 보인다. 가루깍지벌레의 유충과 성충 모두 조사 시점인 4월하순부터 6월상순사이에는 발생량이 증가하다가 7~8월에는 밀도 소강상태를 보인다. 이후 9월 중순에서 10월 중순경에 가을 밀도 최성기를 보인 후 감소하는 패턴이 반복되었다. 해충 조사 대상 과원을 포함한 공검면 일대 150개 배과원에서 가루깍지벌레 주요 방제 시기는 1차 4월중~하순, 2차 6월 상~중순, 3차 7월상순으로 파악 되었다. 방제약제는 amitraz·buprofezin, clothianidin, dinotefuran, buprofezin·thicloprid, buprofezin·dinotefuran등이 주를 이루었다. 현재 후반기 해충 관리는 거의 이루어지지 않고 있는 데, 수확 후 또는 가을철 밀도 증가 이전에 관리의 필요성 제고가 필요하다.

**검색어:** 배, 친환경재배, GAP, 방제시기, 방제약제, 밀도 최성기

P063

## Spatio-temporal distribution pattern of an ambrosia beetle, *Platypus koryoensis*(Coleoptera: Platypodidae) within stands

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Spatio-temporal distribution pattern of an ambrosia beetle, *Platypus koryoensis* (Murayama) which is vector of *Raffaeleaquerci-mongolicae* K.H. Kim et al, a causative agent for Korean oak wilt (KOW) was examined in the stand level. Spatial distribution of *P. koryoensis* was influenced by their density. Relationship between degree of aggregation and density was positively correlated when the density was extremely low or high whereas the relationship was reverse when the density was intermediate. Patch of *P. koryoensis* formed around or near dead trees or partial dead trees, suggesting these trees indicated epicenter of *P. koryoensis*. Fraction of trees attacked by less than 100 individual of *P. koryoensis* in the stand per year increased abruptly whereas fraction of trees attacked over 1,000 individuals of *P. koryoensis* increased gradually. Our results showed that the dead trees would be an epicenter of *P. koryoensis* and the number of trees killed by the ambrosia beetle would be reduced by lowering total population of the ambrosia beetle around the epicenter.

**Key words:** Density dependent, epicenter, Korean Oak wilt (KOW), *Platypus koryoensis*, spatial analysis by distance indices (SADIE)

P064

## **Cold hardiness of overwintering eggs of five *Lycorma delicatula* (White) populations in South Korea.**

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Cold hardiness is an important trait for insects, that enables them to survive during the winter and develop in the next season, and to extend their range. *Lycorma delicatula* (White), which became an important sporadic pest in grapevines and some other fruit trees, has spread rapidly to the most of regions in South Korea. This study was conducted to determine the cold hardiness of overwintered *L. delicatula* eggs according to geographical variation. We collected overwintering eggs in the five sites, Chuncheon, Suwon, Yeongdong, Gunsan, Daegu, on 22~25th Feb. in 2011. We treated eggs to combinations of different temperatures (-15°C, -20°C, -25°C) and exposure time (12hr, 24hr, 3days, 5days, 7days) after chilling them for 24~26 days at 5°C. And then, they were kept in the room temperature. We only analysed three sites of Suwon, Gunsan and Daegu, because of very low hatching rate at Chuncheon and Yeongdong. There were significant effects of time ( $F=36.97$  d.f.=4  $P<0.0001$ ), sites ( $F=17.28$  d.f.=2  $P<0.0001$ ), and the interaction of time and temperature ( $F=5.77$  d.f.=5  $P<0.0001$ ) at -15°C. At -20°C, eggs hatched only at 12hr and 24hr of exposure treatment. All eggs treated at -25°C failed to hatch. It appears that -25°C is around the critical temperature.

**Key words:** *Lycorma delicatula*, egg hatching, cold hardiness

P065

## Okra(*Abelmoschus esculentus* (L.) Moench.)에 발생하는 나방종류와 그 피해 증상

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신규소득작목인 오크라를 가해하는 나비목 유충으로 목화잎밤나방(*Anomis flava* Fabricius), 목화명나방(*Haritalodes derogata* Fabricius), 담배나방(*Helicoverpa assulta* Guenee) 및 왕담배나방(*H. armigera* Hubner)등이 관찰되었다. 이들에 의한 피해는 7월 중순부터 발생하기 시작하여 전체 수확 기간중에 발생하여 지속적으로 피해가 발생하였는데 8월 중하순에 꽃꼬투리의 피해량이 가장 많아 45%의 꽃꼬투리에서 피해가 발생하였다. 목화잎밤나방은 애벌레기에 오크라의 잎과 꼬투리에 피해를 주며 오크라의 모든 개체에서 발생하였는데 잎의 뒷면에 붙어서 부드러운 잎 조직을 갉아먹고 불규칙한 타원형의 구멍을 내거나 꼬투리의 껍질을 가해하였다. 오크라 꼬투리에는 7월 중순부터 피해를 입히는 것으로 관찰되었으며 잎을 말아서 집을 짓는 특징이 있으며 그 안에서 번데기로 변한 다음 성충으로 부화하고 줄기나 열매의 표면에 알을 한 개씩 흩어서 산란하였다. 목화명나방은 유충이 오크라의 잎을 말아서 만든 집 안에서 잎의 뒷면 조직을 가해하여 피해를 주며 가해를 받은 부위는 갈색으로 변하였다.

검색어: 오크라, 목화잎밤나방, 목화명나방, 담배나방, 왕담배나방

P066

## 경북지역 포도원의 꽃매미 월동밀도 및 부화시기

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경북지역의 포도 주산지에서 2010년부터 2011년 2년간 꽃매미 월동실태를 조사한 결과 영천 등 14개 지역에서 월동난괴가 발견되었고 이들 지역 중 영천, 경산, 군위 3지역은 난괴수가 포도나무 1그루에 5개 이상으로 다른지역보다 월동밀도가 높았다. 꽃매미 주요 산란처는 가죽나무, 쉬나무, 두릅나무 등이었다. 지역별 부화시기는 경북 남부지역인 경산, 영천, 경주 3지역의 경우 5월 상순부터 부화되기 시작하여 부화최성기가 5월 중순이었고, 중북부지역은 5월 중순부터 부화되어 최성기는 5월 하순이었다. 지역별 최종 부화율은 평균 71%로 나타났고 봉화지역은 월동하지 못하는 것으로 조사되었다.

**검색어:** 꽃매미, 경북지역, 월동, 부화시기, 부화율

P067

## 땅강아지, *Gryllotalpa orientalis* (Orthoptera: Gryllotalpidae)의 생물학적특징과 인공사육에 관한 연구

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메뚜기목 땅강아지과에 속하는 땅강아지 *Gryllotalpa orientalis* (Orthoptera: Gryllotalpidae)의 생물학적 특징 구명 및 인공사육을 위해 야외에서 300여 개체를 채집하여 25±2℃, 65±10%RH, 16:8LD에서 실험을 진행하였다. 월동을 마친 암컷의 산란전 포란 기간은 평균 35.5일이 소요되었으며, 월동개체의 수명은 평균 85.0일로 조사되었다. 땅강아지의 산란수는 평균 55.2개, 산실당 평균 35.7개로 조사되었다. 사망률은 부화 직후 20.3%이며, 2령 10%, 3령 18%, 4령 20%, 5령 12%로 조사되었다. 산란된 알의 크기는 평균 1.5×1.2mm이었고 부화기간은 평균 18.5일이 소요되었다. 약충의 평균 발육기간은 1령 12.9±1.3, 2령 9.3±0.6, 3령 8.5±2.9, 4령 15.8±1.9, 5령 19.3±5.7, 6령 16.8±2.2, 7령 21.4±2.7, 8령 23.6±4.8일이었고, 합계 116.9±11.5일로 조사되었다. 부화 후 100일까지 각각의 온도에서 발육한 땅강아지의 체장 및 령기(Instar)는 21℃에서 1.7±0.1cm(6령), 25℃에서 1.9±0.1cm(6.7령), 27℃에서 2.4±0.4cm(7.8령)으로 조사되었다. 인공사료는 밀배아(66.1%)를 주성분으로 카제인(18.4%), 염류(5.9%), 소르빈산(1.5%), 메틸파라벤(0.7%), 비타민(7.3%)등을 혼합하여 제작하였다. 인공사료에 파리번데기 체액을 0~20%로 다르게 첨가하여 사육한 결과 발육기간과 사망률에 차이가 없었다. 그러나 인공사료의 생존률은 평균 89.2%로 자연사료만 섭식한경우인 36.1%보다 높았다.

**검색어:** 땅강아지, 인공사육, 발육기간, 인공사료

P068

## 채집기를 이용한 용용가무시증의 매개체인 털진드기(Acarina: Trombiculidae)개체군의 환경 및 계절별 발생밀도 조사

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용용가무시증의 매개체인 털진드기의 채집을 위해 야생설치류를 포획하는 대체 방법으로 고안된 진드기 접촉채집기를 이용하여 2010년 4월부터 2011년 3월까지 경상북도 고령군 및 경기도 화성시에서 계절적 발생밀도 조사를 실시하였다. 조사 기간 동안 고령군에서 1,354개체, 화성시에서 153개체, 총 1,507개체의 털진드기가 채집되었으며, 개체군의 환경별 발생밀도는 각 조사 지역마다 다르게 나타났다. 고령군에서는 논두렁에서 581개체(42.8%)로 가장 많이 채집되었고, 그 다음으로 밭(356개체, 26.3%), 냇가(318개체, 23.5%), 산(99개체, 7.3%)순이었으며, 화성시에서는 밭에서 135개체(88.2%)로 가장 많았고, 수로(11개체, 7.2%), 산(6개체, 3.9%), 밤나무숲(1개체, 0.7%)순이었다. 털진드기 개체군의 계절적 발생양상을 보면 연중 2개의 정점(peak)을 보이는데 4월에 작은 정점을 보인 후 여름에는 채집되지 않았다가 11월에 큰 정점을 나타냈다. 본 조사를 통해 주목할 만한 점으로 가을철 발생 이후 털진드기가 겨울을 지나 봄까지 지속적으로 활동하는 것이 확인되었다. 이상의 채집기를 이용한 진드기 발생밀도조사는 설치류 채집을 통한 밀도조사와 유사한 양상을 보였으며, 보균을 검사와 종합하여 용용가무시증의 유행예측에 적용할 수 있을 것이다.

**검색어:** 용용가무시증, 털진드기, 진드기 채집기, 발생밀도, 고령군, 화성시



P069

## Geographic Genetic Contour of A Leaf Beetle, *Chrysolina aurichalcea* (Coleoptera: Chrysomelidae), on the Basis of Mitochondrial COI Gene and Nuclear ITS2 Sequences

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Ah Rha Wang<sup>1</sup>, Aimei Liao<sup>1</sup>, Tae Hwa Kang<sup>2</sup>, Hae Chul Park<sup>2</sup>, and Iksoo Kim<sup>1</sup>**

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The leaf beetle, *Chrysolina aurichalcea* (Coleoptera: Chrysomelidae), is a pest damaging plants of Compositae. In order to understand the genetic diversity and geographic variation of the species we sequenced a portion of mitochondrial COI gene (658 bp) and complete nuclear internal transcribed spacer 2 (ITS2) collected from seven Korean localities. A total of 18 haplotypes (BARCA01 ~ BARCA18), with the maximum sequence divergence of 3.04% (20 bp) were obtained from COI gene sequence, whereas 17 sequence types (ITS2CA01 ~ ITS2CA17), with the maximum sequence divergence of 2.013% (9 bp) were obtained from ITS2, indicating substantially larger sequence divergence in mitochondrial gene sequence. Phylogenetically, the mitochondrial DNA has shown several haplotypes formed independent groups with substantially high node support ( $\geq 90\%$ ), whereas no such grouping was evidenced for ITS2, indicating different behaviors of the two molecules. Such difference may reflect a diverse dynamics of the species such as biogeographic history, mating behaviors, and also possibly different mode of inheritance of the two molecules, but requires further scrutinized examination of the dataset. In terms of population genetic perspective, overall no population subdivision was detected from both molecules, except for locality 7 (Eocheong islet) from mitochondrial DNA. As more scrutinized analysis is performed, further fruitful inference on the geographic contour of the species might be available.

**Key words:** *Chrysolina aurichalcea*, Geographic Genetic Contour, Mitochondrial DNA, Nuclear DNA

P070

## 항온 조건에서 흰등멸구 [*Sogatella furcifera* (Horvath)] 발육 특성 및 발육모형

박창규, 이시우, 김광호, 박홍현, 이상계

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흰등멸구 [*Sogatella furcifera* (Horvath)]를 10개 항온 (12.5, 15, 17.5, 20, 22.5, 25, 27.5, 30, 32.5, 35°C), 14:10 (L:D)h 광, 상대습도 20-30%의 항온기에서 영기별 발육기간을 조사하였다. 온도별 발육기간을 이용하여 영기별 온도 의존적 발육율 모형과 발육완료 모형의 모수를 알, 어린약충 (1-3령), 노숙약충 (4-5령)으로 구분하여 추정하였다.

알은 12.5°C를 제외한 모든 온도조건에서 발육이 가능하였고 발육기간은 15°C에서 22.5일로 가장 길었으며, 32.5°C에서 5.5일로 가장 짧아 온도가 증가함에 따라 발육기간도 짧아지는 경향을 보였다. 약충은 12.5, 35°C 항온 조건에서 성충까지 발육이 불가능하였으며 발육 가능한 온도 조건에서는 모두 5령을 경과한 후 성충으로 우화하였다. 어린약충 (1-3령)의 경우 15°C에서 발육기간이 27.0일로 가장 길었고 32.5°C에서 4.4일로 가장 짧았다. 노숙약충 (4-5령)은 15°C에서 발육기간이 24.9일로 가장 길었고, 27.5°C에서 4.4일로 가장 짧았다. 알, 어린 약충, 노숙 약충의 발육영점온도는 각각 10.8, 11.8, 12.5°C였고 발육에 필요한 유효적산온도는 각각 104.4, 95.1, 67.8 DD였다.

알 발육에서 온도와 발육율과의 관계를 분석한 비선형 모형들 중 Logan-6 모형을 제외한 모든 모형에서 결정계수 값이 0.96 이상으로 높았으며, 어린 약충과 노숙 약충 발육의 경우 Logan-6 모형을 제외한 모든 모형의 결정계수가 0.99로 극히 높았다. 알, 어린 약충, 노숙 약충의 누적발육완료 패턴을 3-parameter Weibull 함수를 이용하여 분석한 결과 각 발육단계의 결정계수( $r^2$ ) 값이 0.92 이상으로 높아 높은 해석력을 보여 주었다.

**검색어:** 흰등멸구, 발육기간, 온도 의존적 발육 모형, 발육완료 모형

P071

## 곤충병원성곰팡이 *Isaria fumosorosea*에 의한 담배가루이(*Bemisia tabaci*) 자연감염 보고

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담배가루이는 열대성 난방제 해충으로 국내에서는 1998년 장미 재배지에서 처음 발생하였으며, 시설재배지의 화훼 및 채소류에 큰 피해를 주고 있다. 2008년 9월 하순경 경북 성주군 대가면 참외 시설 재배지(위도 35° 53′ 10.96″, 경도 128° 11′ 64.10″)에서 곤충병원성곰팡이에 자연적으로 집단 감염된 담배가루이 성충이 발견되었다. 채집된 감염성충에서 포자를 순수 분리한 후 분리된 균주에 대하여 형태적 관찰과 유전자 분석한 결과 *Isaria fumosorosea*로 동정되었다. 분리된 *I. fumosorosea*-S08은 SDA+Y배지에서 계대 배양(균총 직경 45mm/14day)하였으며, colony는 회색이었다. 직립한 분생자병은 직경이 1.6 $\mu$ m로 크기가 5.3 $\times$ 2.1 $\mu$ m인 long stipe을 지닌 4~6개의 phialide를 가지며, phialide 위의 분생포자는 투명한 타원형의 긴 체인형태로서 크기는 3.0 $\times$ 1.8 $\mu$ m이었다. 균주의 정확한 동정을 위해 5.8S rDNA와 ITS 염기 서열을 분석하고 NCBI 검색 결과 radial root dendrogram 상에서 *I. fumosorosea*와 같은 cluster에 있음을 확인하였다. *I. fumosorosea*는 1999년 국내 처음 토양에서 분리되었으나 담배가루이로부터 분리된 것은 이번이 처음이다.

검색어: 곤충병원성곰팡이, *Isaria fumosorosea*, 담배가루이, 자연감염

P072

## Host Plant Preference of Alfalfa Weevil, *Hypera postica* Gyllenhal (Coleoptera: Curculionidae), against Different Seedlings of Upland Crops

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Alfalfa weevil, *Hypera postica* Gyllenhal, is regarded as one of the most important insect pests on Chinese milk vetch and hairy vetch. The insect usually feed on leaves, stems and pods of the green manure which causes severe reduction of biomass. This study was conducted to observe the occurrence of *H. postica* larva and adult on Chinese milk vetch in 2009 to 2010, and to evaluate host plants preference of 11 different seedlings in 2010, Milyang, Korea.

Occurrence of *H. postica* larvae on Chinese milk vetch was observed to increase from early April clearly and its peak population was showed during middle to late April. The 1st generation of newly emerged adult of *H. postica* was appeared on 20th May. Newly emerged *H. postica* adult was fed on green manure such as Chinese milk vetch and hairy vetch as well as various seedlings located at nearby upland. And then the insects were migrated into aestivating places in middle to late of June. Thus, host plant preference of *H. postica* adults were evaluated with 11 different seedlings using transparent acrylcage and at Chinese milk vetch field. As a result, *H. postica* adult preferred on Chinese cabbage, followed by soybean, kale, foxtail millet and proso millet. The damaged rating of seedlings were shown to have the same trend with adult occurrence. In particular, few *H. postica* adults were occurred on eggplant, lettuce, corn, crown daisy and peanut, and thereby those crops were regarded as non-preference plants due to the absence of damage.

These informations can be used by upland farmers who sowing from late May to early June for effective management of *H. postica*.

**Key words:** Alfalfa weevil, Chinese milk vetch, occurrence, damage, host preference, seedling test, cultivation, upland crop

## 쯔쯔가무시증 매개체인 털진드기 유충의 덕유산 지역 고도별 분포 조사

송봉구, 박원일, 신은희, 노종열, 박찬, 신이현

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쯔쯔가무시증 매개체인 털진드기 유충의 고도별 분포를 확인하고자 유충의 집중 발생시기인 가을철(2009년 11월)과 봄철(2010년 3월)에 덕유산 지역에서 설치류 포획에 의한 털진드기 밀도를 조사하였다. 조사는 북쪽사면인 무주군 설천면부터 빼제고개를 경유하여 남쪽사면인 거창군 주상면일대까지 고도를 200 m 간격으로 나누고 총 16개 지점에 Sherman live trap을 설치하여 설치류를 포획하고 이들에 기생하는 털진드기 유충들을 채집하여 분석한 결과 2과 4속 14종 4,544개체였다. *Leptotrombidium*속은 동양털진드기(*L. orientale*)가 2,248개체(49.5%), 반도털진드기(*L. zetum*)가 712개체(15.7%), 대잎털진드기(*L. pallidum*)가 404개체(8.9%)로 우점을 점하였고, *Neotrombicula*속은 둥근혀털진드기(*N. tamiyai*)가 232개체(5.1%), 사육털진드기(*N. japonica*)가 120개체(2.6%), 광능털진드기(*N. kwangneungensis*)가 106개체(2.3%)로 우점을 점하였다. 고도별 분포로는 동양털진드기와 대잎털진드기가 대부분 지점에서 채집되었으며 반도털진드기는 고도 500 m 지역이상에서 높은 발생밀도를 나타냈다. *Neotrombicula*속은 500 m 지역이하에서 높은 발생밀도를 나타냈다. 계절별로는 *Leptotrombidium*속이 가을철보다 봄철에 높은 발생밀도를 보였고, 반면에 *Neotrombicula*속은 봄철에 낮은 발생밀도를 보였다. *Leptotrombidium*속은 고도와 계절에 따른 분포 차이가 거의 없는 것으로 나타났으나 *Neotrombicula*속은 계절적인 영향은 받는 것으로 나타났다. 이러한 결과는 지역 주민 및 관광객들에게 쯔쯔가무시증의 예방을 위한 홍보 및 방제의 기초자료로 적용할 수 있을 것이다.

**검색어:** 쯔쯔가무시증, 털진드기 유충, 덕유산, 고도별 분포

P074

## Sampling of *Unaspis yanonensis* (Hemiptera: Diaspididae) in Citrus Orchards, Jeju

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Arrowhead scale, *Unaspis yanonensis*, is a serious scale insect pest of citrus in Jeju. The sticky taping of 1.0 cm diameter twig was a good survey method for arrowhead scale crawler. There are three times crawler occurrence season - late May to early July, late July to middle September and late September to late October. But the third occurred crawlers are all died during overwintering in open-field groves. This study was conducted to provide information on efficient sampling plan for arrowhead scale within the tree. Twig and fruit was fit for secondary sample unit by two-stage variance analysis. Both sample number per tree (primary sample unit) was eight twigs or fruits. Taylor's power law was better described the distribution characteristic of arrowhead scale than Iwao's patchiness regression. The slope of both linear regressions was greater than "1" which means aggregative distribution pattern. Minimum sample size to estimate the density was calculated using by two parameters of Taylor's power law. To estimate the mean density on twig and fruit by binomial sampling plan, the optimum tally threshold was 5 and 7, respectively.

**Key words:** *Pseudococcus cryptus*, sex pheromone, trap, monitoring, *Anagyrus* sp.

## Occurrence and route tracking of *Riptortus pedestris* (Hemiptera:Alydidae) in Chungbuk province

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This study was conducted to determine the occurrence and route tracking of *Riptortus clavatus* from 5th April to 10th November, 2010. Investigation area was selected: farmland at Chungbuk National University (CBNU), Jujung-dong (Cheongju) and O-Chang (Cheongwon) that distinguished the farmland and the forest, and two sites by an altitude at Mt. Yangseong (Munui-myeon, Cheongwon). Aggression pheromone trap (below trap) and trap+soybean are set on two sites by an altitude of Mt. Yangseong farmland (80m) and forest (200 and 300 m). Population density of *Riptortus pedestris* showed the highest in Mid-Jun., Mid-Aug, and Late-Oct., and caught more trap+soybean than trap. Two sites of O-Chang and Jujung, *R. pedestris* was more caught to a farmland in June to August, but caught to forest at Sept. Comparison between traps, trap+soybean is more caught than trap, higher caught in season to a farmland from Jun. to Aug., a forest from Sept. to Nov. Farmland of CBNU without forest was caught from Mid-Jul. to Late-Aug, and the number of caught insect was higher in trap+soybean. This pattern caught more in trap+soybean shows the similar result from five investigation area but showed the difference according to the investigation area. *R. pedestris* was released after marked with fluorescent paint for route tracking. Ten days after release of 500 density at 200 m altitude (25th Aug), *R. pedestris* was re-caught seven in the same altitude, but the release at 80 m altitude (4th Oct.), *R. pedestris* was re-caught at 200 and 300 m. This result suggest that *R. pedestris* did not move in August to other altitude because of rich-food, however, *R. pedestris* seems to move in Oct. to the forest by reason of food-shortage or overwintering.

P076

## Calling song evolution and speciation in three closely related cricket species

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To understand the evolution and speciation of closely related species, a multiple approach encompassing morphological, behavioral, and genetic analyses is necessary. In Korea, three species of *Loxoblemmus* crickets occur widely. *L. campestris* and *L. equestris* are morphologically indistinguishable, whereas males of *L. doenitzi* are different from the other two species in head morphology. The genetic analyses using the partial mitochondrial COI sequences showed that *L. doenitzi* diverged off earlier than *L. campestris* and *L. equestris*. The analyses of laboratory recordings revealed that distributions of calling song characters generally overlapped among three cricket species. However, the number of pulses in a chirp was two in *L. doenitzi* and four in *L. campestris*, but it was greater than or equal to six in *L. equestris*. Provided that females make mate choice based on this calling song character, the differentiation in this character may lead to premating reproductive isolation and may have evolved during the speciation process in these closely related species.

**Key words:** cricket, *Loxoblemmus*, calling songs, speciation



## Recovery, Occurrences and Natural Infection Rates of *Romanomermis* sp.(Mermithidae; Nematoda) Mosquito Parasite in Korea Agroecosystem

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Field research was undertaken for recovering mosquito larval mermithid parasite, *Romanomermis* species in rice fields in 54 different areas in period of May through October, 2009. Of 54 area rice fields surveyed, *Romanomermis* sp. recoveries were made from 4 areas. 32 *Anopheles* mosquito larvae, malaria disease vector were infected and died from samples collected in Pochon area, and a total of 10 *Culex* mosquito larvae, house frequenting mosquito were infected to death in 3 different areas, Gimpo, Sangju and Gurae, respectively. On the basis of positive natural infection record, an intensive host-parasite occurrences and/or population study was surveyed in foci area of Pochon in small pond (P) and Rice paddies (A and B) during 5 months till end of October. The natural mermithid infection was continuously occurred from June through October in weekly samples, however the rate of infection was appeared higher in June-July, thereafter the rate gradually decreased in progress of the season. The highest natural infection rate was observed from the Pond 9.1% followed by Rice paddy "A" 5.2%, Rice paddy "B" 2.4%, respectively. Including 2 other Rice paddies "C" and "D", a total mosquito larvae collected was 3,270, an overall average natural infection rate was recorded as 3.7% (121 *Anopheles* mosquito larvae infected).

**Key words:** *Romanomermis*, *Anopheles*, *Culex*, mosquito parasite, natural infection rate, seasonal occurrence, geographical distribution, foci area, Mermithid parasite

P078

## 감귤 품종이 귤응애(*Panonychus citiri*) 발육 및 산란에 미치는 영향

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귤응애(*Panonychus citiri*)는 제주도 감귤의 중요한 해충으로, 감귤 품종에 따른 귤응애의 발육과 산란의 영향을 알아보기 위하여 본 연구를 수행하였다. 실험에 사용된 감귤의 품종은 궁천, 부지화, 청견, 세또카, 레몬, 지각으로, 이 중 궁천이 제주도에서 가장 많이 재배되는 품종이다. 실험은 각 품종의 경화된 잎(2cm×2cm)에서 자란 암컷이 산란한 알을 이용하여 알, 유충, 제 1약충, 제 2약충의 발육기간을 조사하였다. 성충의 수명과 산란수는 성충으로 된지 1일된 암수 각각 1마리를 접종하여 암컷의 수명과 산란수를 조사하였다. 실험은 온도 23±1℃, 70±10%, 16L8D 광조건에서 24시간 간격으로 조사였다. 궁천의 잎에서 귤응애 알, 유충, 제 1약충, 제 2약충의 평균 발육기간은 각각 8.5, 2.1, 2.0, 2.8일이었다. 암컷 성충은 평균 11일간 생존하면서 27.3개의 알을 산란하였다. 감귤 품종에 따라 귤응애 알, 약충 발육기간과 산란수에 통계적으로 유의한 차이가 있었다. 궁천과 비교하여 제 2약충 발육기간은 청견이 1.1일, 세또카와 지각이 약 0.8일, 레몬과 부지화가 약 0.5일 더 빨리 발육하였다. 산란수는 부지화가 궁천조생에 비해 45% 증가하였다.

**검색어:** 귤응애, 감귤, 발육기간, 산란수

P079

## Geographic Genetic Contour of a Ground Beetle, *Scarites aterrimus* (Coleoptera: Carabidae) on the Basis of Mitochondrial DNA Sequence

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The *Scarites aterrimus* (Coleoptera: Carabidae), is one of the carabid beetles dwelling exclusively on coastal sandy dunes. Recent habitat deterioration has greatly concerned population declines in several species dwelling on the coastal sandy dunes. As a first step to establish long-term conservation strategy, we investigated the nation-wide magnitude and nature of genetic diversity of the species. As a first step, we sequenced a portion of mitochondrial COI gene, corresponding to “DNA Barcode” region (658 bp) from a total of 24 *S. aterrimus* individuals collected over nine sandy dunes belonging to four Korean provinces. The sequence analysis evidenced moderate to low magnitude of sequence diversity compared with other insect species distributed in Korean peninsula (0.152% to 0.912%). The presence of closely related haplotypes and relatively high gene flow estimate collectively suggest that there had been no historical barriers that bolster genetic subdivision. Population decline was postulated on the basis of several missing haplotypes that are well found in the species with a large population size. This interpretation is consistent with field observation of small population size in the coastal sandy dune habitats. The highest genetic diversity estimates were found in the coastal sand dune population of Seogwipo, Jeju Island, justifying a prior attention to the population, in order to sustain overall genetic diversity of the species. Further scrutinized study might be required for further robust conclusion.

**Key words:** *Scarites aterrimus*, Geographic Genetic Contour, Mitochondrial DNA

## 오미자 줄기를 가해하는 해충의 생태적 특성

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최근 DDA, FTA 협상 등으로 인해 국가간 경제교류와 통합 등이 활발하게 진행되고 있으며 국제적으로 통용될 수 있는 우수농산물관리제도(Good Agricultural Practices, GAP)등의 농산물의 식품안전성 문제가 대두되고, 농산물을 안전하게 생산하는 것은 건강 유지뿐만 아니라 환경에 미치는 위해요소를 제거하여 생태계 보존 및 청결한 과원 관리가 절실하게 요구되고 있다.

오미자는 주로 해발 300m이상 되는 고랭지 지역에서 재배되고 있는 덩굴성 식물로 수명은 8-12년 정도 되는 우리나라 약용작물 중의 하나다. 특히 최근에 오미자의 맛과 효능이 소비자로부터 인정을 받으면서 재배면적이 전북 동부산악권(무주, 진안, 장수, 남원, 순창)을 중심으로 날로 증가하고 있는 실정이다. 그러나 오미자 재배면적이 집단화 규모화 되면서 병해충의 발생양상도 다르게 나타나- 오미자에 대한 주요 병해충을 파악하여 방제의 기초자료 제공 및 병해충의 위험도를 평가하고자 이에 대한 실태를 조사 한 결과 오미자에 주로 발생하는 해충은 오미자 식나무꼭지벌레가 피해가 많았으나 오미자 식재년수가 늘어나고 노후화 과원이 증가하면서 포도유리나방 및 신종 해충으로서 검은점애바구미(*Dendrobaris maculata*(Roelofs, 1879))가 발생하여 농가의 피해가 확산되고 걱정거리로 대두되었다. 따라서 오미자 줄기를 가해하여 나무의 일부 또는 전체를 고사시키는 포도유리나방과 오미자 신종해충인 검은점애바구미의 사진자료와 피해증상을 보고하고, 오미자 줄기를 가해하는 주요 해충에 대한 정보를 공유하며, 병해충별 정확한 생리생태와 방제방법, 친환경 방제자재 선발 등을 연구함으로써 농가의 안정생산에 기여하고자 한다.

**검색어:** 오미자, 줄기가해 해충, 포도유리나방, 검은점애바구미, 생태

## 제주도 차밭에서 관행과 유기재배 시 차나무 주요 해충의 발생 비교

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제주도 서귀포시 도순동에 위치한 조사 다원은 1982년 조성 되어 2008년부터 유기재배로 전환하여 차를 재배하고 있다. 본 연구는 관행재배기(2002~2007년)와 유기재배기(2008~2009년) 차나무 주요 해충의 발생 밀도를 비교하여 유기재배 후 해충의 발생 변화를 조사하고자 본 연구를 수행하였다. 차응애는 두물차 생육기인 5~6월에 밀도가 높으며 6월 말부터 밀도가 낮아지는 것으로 관찰 되었고, 유기재배와 관행재배에서는 발생 밀도의 차이가 없었다. 오누키애매미충은 관행재배에 비해 유기재배에서는 두물차 생육기 밀도가 높고 이후 밀도가 낮아져 이 시기에 집중적으로 관리가 필요한 것으로 판단되었다. 볼록총채벌레는 관행재배에서 두물차기와 세물차기에 높은 밀도를 보였지만, 유기재배 전환 후 발생 밀도가 낮게 나타났다. 차잎말이나방은 연 4회의 발생을 볼 수 있었고, 유기재배 첫해인 2008년은 성페로몬 트랩 당 연간 771.2마리로 높은 발생 밀도를 보였지만, 2년 차인 2009년은 트랩 당 연간 80마리로 낮은 밀도를 나타내어 해마다 발생 밀도의 차이가 크게 나타났다. 동백가는나방은 연간 5회의 발생 피크를 보였으며, 유기재배 첫해인 2008년은 트랩당 평균 2,779마리가 2009년은 4,143마리가 유인되어 유기재배 후 밀도가 증가하는 것으로 나타났다. 본 연구에서 유기재배 전환 후 볼록총채벌레와 차잎말이나방은 유기재배 전환 후 밀도가 감소하였으며, 동백가는나방의 밀도가 증가하는 것으로 나타났다. 차응애와 오누키애매미충은 두물차 이후에는 발생이 감소하는 것으로 나타났다.

**검색어:** 차응애, 오누키애매미충, 볼록총채벌레, 차잎말이나방, 동백가는나방

P082

## 복숭아혹진딧물(*Myzus persicae*)의 파프리카 품종에 대한 기주선호성

윤규식, 권혜리, 강민아, 박민우, 조신혁, 신호섭,  
김세희, 서미자, 유용만, 윤영남

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파프리카를 가해하는 복숭아혹진딧물의 국내 전남지역의 수출농가에서 많이 재배되고 있는 파프리카 품종에 대한 기주 선호성을 조사하였다. 파프리카 15품종을 선발하여 각각의 EPG 패턴을 관찰함으로써 복숭아혹진딧물의 섭식행동을 알아보고 생명표작성 조사를 통하여 생태학적 측면을 관찰함으로써 품종간 기주 선호성을 비교연구하였다. 복숭아혹진딧물이 각 품종에서체관부 섭식시간은 Orobell과 Thialf 품종에서 짧은 시간동안 이루어졌고, Ferrari, Jinju, Rapido 품종에서 흡즙하는 시간이 길었다. 또한 구침을 빼고 섭식하지 않는 시간은 Ferrari, Jinju, Rapido 품종에서 짧게 나타났고, Orobell, Thialf 품종에서 길게 나타났다. 생명표를 비교하여 보면, 총 산자수와 내적자연증가율(rm)은 Coletti, Mazzona, Rapido, Scirococo 품종에서 낮았고 Debla, Ferrari, Orange Glory, Jinju 품종에서 높았다. 총 산자수와 내적자연증가율(rm)은 체관부 섭식시간과 비례하여 나타나지는 않았다. EPG 패턴분석과 생명표를 분석하여 종합한 결과를 미루어 추측하면 복숭아혹진딧물이 선호하는 품종은 Ferrari, Jinju, Orange Glory 품종 등이었고, Orobell, Purple, Thialf 품종 등은 다른 품종에 비하여 덜 선호하였다.

검색어: *Myzus persicae*, EPG, life table, varieties

P083

## Current Status and Agriculture Utilization of Commercial Managed Insect Pollinators in Korea

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Commercially managed bees are available for pollination services and are used in large commercial fields, small gardens, or enclosures such as greenhouses and screen houses. We investigated the use rate and number of commercial bees such as bumblebees, honeybees and mason bees for the pollination of 10 major horticultural crops and fruit trees in Korea. The use rates of bumblebees for 10 major horticultural crops and fruit trees were approximately 7.9% and 2.8% in 2009, respectively. The use numbers of bumblebees as pollinators was more than 64,345 colonies which included 51,400 for 10 major horticultural crops and 12,945 colonies for 10 major fruit trees, in 2009. The use rate of honeybees as a pollinator for 10 major horticultural crops in greenhouses and fruit trees were approximately 48.0% and 7.7%, respectively. The number of hives used for 10 horticultural crops and fruit trees was estimated to be 305,216 and 32,386, respectively. The number of honeybees hives used for pollination of 10 major horticultural crops and fruit trees was estimated to be 337,602. The use numbers of honeybees as pollinators was more than 337,602 hives in 10 major horticultural crops and fruit trees, in 2009. The number of honeybee hives used as pollinators of outside crops, including many fruits and vegetables, was estimated to be more than 500,000. The value of honeybees as pollinators was estimated to be more than 8.5% to 15.0% of total Korean beekeeping products. The rate of use of mason bees for 10 major fruit trees was approximately 3.3%. The number of mason bees individuals used for 10 major fruit trees was estimated to be 1,350,000. The value of commercial insect pollinators in 2009 in Korea was estimated at more than \$45 million.

**Key words:** Agriculture utilization, Insect pollinator, Bumblebee, Honeybee, Mason bee

P084

## Occurrence and Developmental Characteristics of Maize Weevil

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We have gathered rice grain and bran from conventional mills and RPC(Rice Processing Complex) for the survey of stored grain insect pests.

Maize weevil(*Sitophilus zeamais*) is the dominant species among the stored grain insect pests of the rice grain and bran. Under three constant temperatures, 15, 20 and 25°C, developmental periods from egg to adult were 43.0, 37.5 and 29.2 days, respectively. With egg periods being 9.6, 7.3 and 5.2days, and larval periods being 25.2, 21.8 and 19.8days, and adult periods being 126.1, 110.3 and 108.6days, respectively. The adults of Maize weevil feed basically on the same the foods as the larvae but not as restricted in their diets because the larvae need to develop inside whole grains. Feeding of *S. zeamais* adult usually began 3~4 days after emergence at 25°C. Then adult feeding ca. one rice a day, reaching a peak of 20~40days after emergence.

**Key words:** Stored grain insect pests, Maize weevil, Developmental periods



P085

## Population density of Insect Pests and Natural enemies in the Rice Field

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Biological control of rice insect pest is an important component of an IPM program. There are many species of natural enemies which contribute to the suppression of rice pest populations below economic injury levels. In order to use biological control more efficiently, it is a need to identify beneficial species and determine their roles in possible regulation of insect pests. There is a rich complex of biological control agents in rice and bund. This research was carried out to investigate the population density of insect pests and natural enemies in the rice field and bund. A total of 7 pest species and 15 natural enemy species were collected in the rice field. 10 pest species and 20 natural enemy species were collected in the bund, also. Changes in population density of insect pests and its prey were investigated in the rice field and bund. Population densities of insect pests were low at any time during the rice growth period in the field. This could be the high density of natural enemies. Bunds served as refuge for natural enemies when rice maturity. There are rich complex of biological control agents in rice field and bund. So, when we practice integrated pest management(IPM) of rice insect pests, we should use various natural enemies.

**Key words:** Rice, Population density, Insect Pests and Natural enemies

## Host Plants and Seasonal Occurrence of *Popillia flavosellata* (Coleoptera: Rutelidae)

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Host plants of insect pest in turfgrass and ornamental tree, *Popillia flavosellata* (Coleoptera: Ruteridae) were investigated in golf courses and forest. Twenty six species in 18 families were observed to be fed on from this research and 22 species in 15 families were recorded newly host plants of *P. flavosellata*. Thus, total number of host plants of *P. flavosellata* were 49 species in 23 species. *P. flavosellata* adult mainly fed on flower of host plants. Seasonal prevalence of *P. flavosellata* adult was investigated in East Valley Country Club in Gwangju, Gyeonggi, Korea using Japanese beetle pheromone lure and a eugenol feeding attractant. Peak activity of *P. flavosellata* adult was nearby 20 June. Mean attracted number of *P. flavosellata* adult at peak day were 197.6 individuals/trap/day at 2008 and 268.1 individuals at 2010. Occurrence of *P. quadriguttata* were very lower then *P. flavosellata*. Mean attracted number of *P. quadriguttata* adult at peak day were 17.5 individuals/trap/day at 2008 and 2.3 individuals at 2010 in same trap.

**Key words:** Golf courses, *Popillia flavosellata*, host plant, turfgrass insect pest, seasonal occurrence

P087

## Comparison on the pollinating effect and activity relative to the comb number in honeybee hive released in the strawberry (Seolhyang var.) houses

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The time-zone of pollinating activity relative to numbers released of *Apis mellifera* in the strawberry(Seolhyang var.) houses was together from 9A.M. to 4P. M., and the peak time of pollinating activity was 11A.M.. The effects on pollinating activity relative to the comb number in the honeybee hive released at the strawberry houses were ordered 5bee combs(11,000heads), 4bee combs (8,800heads) and 3bee combs (6,600heads). The rate of workers lost in *A. mellifera* hives with 5bee combs and 4bee combs during the strawberry cultivating period were lower than that of 3bee combs. The rates of fruit set by pollinating activity relative to the comb number in the honeybee hive released at the strawberry houses were same level with over 98%. The fruit qualities; No. of seeds, sugar content and rate of normal fruit set were same level, but fruit weights were ordered 5bee combs in 37.2g, 4bee combs in 35.6g and 3bee combs in 32.6g. The marketing incomes of 4bee combs and 5bee combs were 9% to 13% higher than that of 3bee combs, respectively.

**Key words:** Strawberry, *Apismellifera*, Maehyang var. pollinating activity, bee comb.

P088

## A Long-Term Comparative Study on Macrolepidoptera Diversity in Three Types of Vegetations from Worak-san [Mt.] in 2010

So-Young Lee, Eunsol Lee, Seongkyun Lee, Seulki Kim, Taeho Kim, Chang gi Hong, Hyungjin Park, and Soowon Cho

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We have surveyed monthly diversity and seasonal prevalence of Macrolepidoptera in Wol-ak-san [Mt.] for the period of four months from May to August in 2010. Although it is not a part of KLTER/ME and KLPS study in Wol-ak-san conducted in recent few years, this year's data may be comparable with the previous ones as the collection sites and dates are very similar. The three representative vegetations are *Quercus mongolica*-, *Quercus variabilis*- and *Pinus densiflora*-formations, abbreviated as QM, QV and PD, respectively, and we collected exclusively larger moths with bucket-type of light traps for quantified survey.

In 2010, as a result, QV showed higher species diversity and specimen number than QM or PD although the differences between QV and QM are very subtle. The result is very similar to the result in 2009. The only difference in 2010 over 2009 is that the number of species, not specimens, has been increased 1.5 times, and this may be caused by the inclusion of July records, which has been usually deleted due to heavy rainy season causing poor collection records.

The number of species in Noctuidae was the highest in 2010, about twice more than that in 2009, but the dominant species in 2010 were either Pyralidae (*Nacoleia commixta* or *Bradina geminalis*) or Geometridae (*Arichanna melanaria*).

We are still experiencing decline of specimen numbers: 567 specimens collected in 2010 while 651 in 2009 and 874 in 2008, which was already a huge reduction compared to over 2500 specimens in 2007.

**Key words:** Mt. Worak [Wol-ak-san], Macrolepidoptera, biodiversity monitoring

P089

## Effects of Insect-Resistant Genetically modified Rice on the Rice Insect Community

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Field studies were conducted to assess potential effects of transgenic rice expressing *Bacillus thuringiensis* (Bt) CryIAc1 protein, which is highly effective the rice leafroller, *Cnaphalocrocis medinalis*, on the rice insect community in 2007 and 2008. Insects were sampled in non-*Bt* and *Bt* rice plots with a sweep net and a suction devise. A total of 64,256 individuals in 45 families and 11 orders (30,860 individuals in 43 families and 11 orders in the *Bt*-rice plots, and 33,396 individuals in 40 families and 11 order in the non-*Bt* rice plots) were captured and grouped by ecological functional guilds. Species diversity and richness were not significantly different between *Bt*-rice and non-*Bt* rice plots. The seasonal pattern of the insect community and the seasonal population fluctuation of insects were very similar between two plots. Collectively, the rice insect community was not influenced by the *Bt*-rice in the present study.

**Key words:** *Bt*, transgenic rice, insect resistant, *Cnaphalocrocis medinalis*, non-target effect, insect community

P090

## The Latest Occurrence of Sporadic and Major Insect Pests in Gyeonggi Province Area

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and Sung Ki Kim

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This study was conducted to investigate the occurrence patterns of sporadic and major insect pests in Gyeonggi Province Area. Lantern fly (*Lycorma delicatula*) damages to reduce the yield and quality of commodities in grape orchard begin to emergence from the early May, and new adults have appeared from the middle July lay eggs till the early November. The hatchability of eggs laid in last year was influenced by the extremely low temperature (especially  $-20^{\circ}\text{C}$  and under) in over-wintering season. Sweet-potato whitefly (*Bemisia tabaci*) is widely distributed in the southern part of gyeonggi province, and the biotype of most regional populations is Q-type except the partial Goyang area population (B-type). Potato tuber moth (*Phthorimaea operculella*) had been reported firstly in 2009 expanded and was confirmed in the northern part of gyeonggi province in 2010. Citrus flatid planthopper (*Metcalfa pruinosa*), becoming an issue in Korea, have been detected apple (Paju), pear (Yongin, paju), grape (Paju) orchards in 2010.

**Key words:** sporadic insect, lantern fly, sweet-potato whitefly, potato tuber moth, citrus flatid planthopper, gyeonggi

P091

## **Inhibition of feeding behaviors using acoustic stimuli in aphids: Playback experiments**

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The green peach aphid, *Myzus persicae* (Sulzer), is one of the most important insect pests in the world. We have explored the possibility of using sounds as a control agent in this species. Sine waves with four different frequencies (100, 500, 1000, 5000 Hz) were used as acoustic stimuli in the playback experiments. As a behavioral bioassay, we recorded honey dew production (HDP), wagging, and walking. HDP occurs regularly at each stage of nymphal and adult periods, and the rate of HDP may indicate a degree of food consumption. Aphids conduct wagging to determine a host plant or to find a feeding site. Walking may be regarded as dispersal. All acoustic stimuli significantly reduced the rates of HDP and increased the rates of wagging. There were no significant effect of acoustic stimuli on walking. Based on the bioassay, the acoustic stimulus with 5000 Hz seemed to be the most effective on inhibiting feeding behavior of this aphid species at an individual level.

**Key words:** aphid, green peach aphid, acoustic-stimulus, pest-control, honeydew-production

P092

## **Effect of teflubenzuron (chitin synthesis inhibitor) on biological trait of *Paranura rosea* (Collembola)**

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The use of insect growth regulators (IGRs) has been gaining popularity as an environmentally friendly option to improve existing integrated pest management (IPM) strategies. Although IGRs have a selective effect on target organisms, they may exert a more selective effect on non-target organisms. In this study, the toxic effects of teflubenzuron on biological traits of *P. rosea*, Collembola, were assessed in the OECD artificial soil under two different exposure conditions, one was exposed in the bulk soil, and the other was exposed in the compacted soil which unidirectional force was applied to the soil surface. After 28 days of exposure, the toxicity of teflubenzuron on the survival and juvenile production of *P. rosea* in the bulk system was more toxic than that of the compact system. Moreover, not only the egg production but also the hatching rate and molting frequency of *P. roseas* was decreased in a concentration dependent manner. These results suggest that the IGRs teflubenzuron exhibit significant impacts on the biological traits of non-target organisms *P. rosea* and its toxic effects are differently assessed depending on the exposure conditions.

**Key words:** Teflubenzuron, Collembola, *paranura rosea*, bulk system, compact system



P093

## 사슴풍뎡이(*Dicranocephalus adamsi*) 발생 특성 및 사육을 위한 환경조건

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경기도농업기술원 소득자원연구소에서는 2007년부터 DMZ 서식 곤충자원을 조사결과 산업화 유망곤충으로 사슴풍뎡이(*Dicranocephalus adamsi*)를 선발하여 대량사육체계와 산업화를 연구중이다. 경기도 연천지역에서 유인트랩을 설치하여 사슴풍뎡이 발생소장 조사 결과 성충 출현시기는 5월 상순 ~ 6월 하순이었으며 발생최성기는 5월 하순이었다. 서식처 주변 삼림구조는 침엽수보다는 활엽수 군락지였고, 해발 150m 이하의 낮은 숲과 주위에 계류가 있는 곳으로 나타났다. 곤충 사육체계중 먹이와 사육환경은 매우 중요한데, 25°C 온도에서 유충의 먹이로 참나무발효톱밥만 사용하였을 때는 성충으로 발육이 되지 않았으며, 부엽토 50% 첨가한 배지에서 성충우화율 73.3%, 부엽토 75% 첨가한 배지에서 86.7%로 높았고, 성충크기도 자연 채집개체와 차이가 없이 정상적으로 사육할 수 있었다. 성충 먹이로 곤충전용젤리를 급여하였을 때 산란은 참나무 발효톱밥에서 높았고, 광주조건은 8L:16D, 온도조건은 18~20°C로 어둡고 서늘한 환경을 선호하는 경향이 있었다. 알기간은 10.3±0.6일, 유충기간은 1령, 2령, 3령 각각 12.6±2.4일, 17.8±3.5일, 31.6±2.4일, 번데기기간은 24.3±1.0일로 알에서 성충으로 우화하는데 91일±3.3일이 소요되었으며, 암컷 성충의 산란기간은 31.2±10.3일, 산란수는 23.3±6.6개 이었다.

이상의 연구결과 사슴풍뎡이 유충은 25°C 온도조건에서 먹이로 참나무발효톱밥에 부엽토 75% 첨가한 배지에서, 성충은 18~20°C 온도, 8L:16D 광주조건에서 먹이로 곤충전용젤리를 급여하였을 때 정상적으로 사육할 수 있었다.

**검색어:** 사슴풍뎡이, 곤충, 사육

P094

## 매미나방(나비목: 독나방과)의 생활사

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매미나방(*Lymantria dispar* (Linne))는 나비목(Lepidoptera) 독나방과(Lymantriidae)에 속하며 한국을 포함하여 유럽부터 일본에 이르는 구북구지역에 분포하는 해충이다. 자연 상태에서는 많은 천적과 병원체로 인하여 크게 피해를 주지 않는 것으로 알려있으나 유럽계통 매미나방의 유입으로 미국 북동부, 캐나다 남동부에 막대한 피해를 주고 있어 북미식물보호기구(North American Plant Protection Organization)는 새로운 지역으로의 유입을 막고자 심혈을 기울이고 있어 검역적으로 중요한 해충이다. 본 연구에서는 매미나방의 생활사를 구명하고자 2009년과 2010년에 산란된 난괴를 사육용기에 넣고 온도 25°C, 습도 60%, 명암 14L:10D인 항온항습실에서 실내사육하였다. 먹이는 인공사료를 냉장보관하며 공급하였으며, 유충의 충태별 형태와 두폭 및 생육기간 등 생활사를 조사하였다. 매미나방 1령~5령 및 6령(암컷)에 대한 두폭크기는 0.63, 1.17, 1.90, 3.31, 4.35 및 5.65mm이며, 변이계수는 2.52, 2.07, 6.32, 11.82, 4.25, 및 0.72%였다. 암컷의 1령에서부터 번데기까지의 생육기간은 6.5±0.9, 4.2±0.8, 3.4±1.2, 4.5±1.2, 5.3±2.3, 8.7±3.5, 13.2±1.8일이고, 수컷은 6.8±1.1, 4.0±0.6, 3.6±1.3, 5.9±1.5, 10.8±2.6, 14.9±0.3일이며, 총 발육기간은 암컷 44.7±2.5일, 수컷 45.1±2.0일이다. 3령까지는 암수가 비슷한 발육기간을 가지다가 4령부터 암컷의 성장이 빨라지고 먹이섭식이 왕성해지며 한 단계의 영기를 더 가지게 되지만 수컷이 4령부터 번데기 시기의 생육기간이 길어져 실제 우화시기는 일치하는 것으로 보아 실제 자연 상태에서 성충의 발생시기는 일치한다는 것을 알 수 있다.

**검색어:** 매미나방(*Lymantria dispar* (Linne)), 생활사, 형태, 산란, 우화

P095

## 넙점꼬마강변먼지벌레와 배추벼룩잎벌레 발생소장 비교

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넙점꼬마강변먼지벌레가 배추벼룩잎벌레 유충의 천적으로 활용 가능성이 있는지를 알아보기 위하여 전북 김제시 백산면 양배추 포장(3000m<sup>2</sup>)에서 양배추 생육 기간동안 배추벼룩잎벌레와 넙점꼬마강변먼지벌레의 발생소장을 조사하였다. 배추벼룩잎벌레의 발생소장은 2008년 5월 상순 발생을 시작하여 점점 증가하고 6월 하순 발생피크를 보이고, 이후 감소하는 경향이였다. 2009년에도 비슷한 발생 경향을 나타내었다. 배추벼룩잎벌레 발생밀도는 최고 5.5마리/엽으로 매우 높은 경향이였다. 동일포장에서 넙점꼬마강변먼지벌레는 6월 상순부터 발생을 시작하여 8월까지 발생밀도가 증가하였고, 최고 2.9마리/m<sup>2</sup>였으며, 배추벼룩잎벌레 발생양상과 비교하여 볼 때 배추벼룩잎벌레 밀도가 먼저 증가하고, 이후에 증가하며, 발생피크가 배추벼룩잎벌레보다 늦게 나타나는 전형적인 천적의 발생양상을 보였다. 발견된 넙점꼬마강변먼지벌레는 토양표면과 땅속을 빠르게 이동하며 톱토기, 잎벌레 유충 등 토양표면 또는 토양내 미소동물을 잡아먹는 곤충으로 천적으로써 활용 가능성이 있으며, 넙점꼬마강변먼지벌레가 발견된 김제 양배추 포장은 양배추, 배추, 무 등을 10년이상 친환경으로 재배하였던 포장이기 때문에 자연적으로 천적류도 많이 발생할 것으로 추정되어 좋은 연구대상이 될 것으로 보인다.

**검색어:** 발생소장, 천적, 배추벼룩잎벌레, 넙점꼬마강변먼지벌레, 양배추

P096

## Monitoring of *Anopheles* mosquito population and *Plasmodium vivax* infection from the mosquito species in malaria epidemic areas in the Republic of Korea (ROK) 2010

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Density of malaria vector mosquitoes, *Anopheles* mosquitoes, and infection of *Plasmodium vivax* from the vector mosquitoes were monitored at 9 surveillance points in Incheonsi, 12 in Gyeonggi province and 7 in Gangwon province in the Republic of Korea (ROK) from April to October of 2010. The seasonal numbers of *Anopheles* mosquitoes collected weekly showed a high degree of variability. A total of 4,435 mosquitoes were captured using black light traps. Members of the *Anopheles* mosquito group were the most abundant species and accounted for 71.8% of the mosquitoes collected. The majority of this species were collected from Incheonsi (86.2%), particularly from Ganghwagun (84.8%). During June, populations of this species steadily increased and peak at second week of July. Thereafter, populations of this species decreased by the second week of August and increased by the third week of August, again. *Anopheles* mosquitoes steadily decreased from the fourth week of August. First *Anopheles* mosquitoes were reported in Wolgotri (15th weeks/year), Ganghwagun, Incheonsi, followed by Tanhyundong (16th weeks/year), Pajusi, Gyeonggi Province and Daemari (17th weeks/year), Cheolwongun, Gangwon Province. In Ganghwagun in which the most abundant malaria patients (102 patients) were reported, *Anopheles* mosquitoes demonstrated the highest species portion (over 70%) among collected mosquito species from July to September. Infection rate of *P. vivax* from the *Anopheles* mosquitoes also was the highest in Ganghwagun. In Gangwon and Gyeonggi provinces, collection rate of *Anopheles* mosquitoes and infection rate of *P. vivax* were relatively lower than those of Ganghwagun. Reported malaria patient cases in Gangwon and Gyeonggi provinces also were relatively lower than those of Ganghwagun. However, detailed results showed that there were some sites in which any correlation between malaria patients and vector mosquitoes were not. This may be resulted from size of surveillance area. Smaller size of surveillance area was, higher accuracy of analysis on correlation between vector mosquitoes and patients was. Further studies on relationship between malaria vector and patients may need for more accurate analysis, such as increase of collection site and so on.

**Key words:** *Anopheles* vector mosquitoes, *Plasmodium vivax*, Republic of Korea

P097

## 제주 낙과감귤에 발생하는 밀빠진벌레과 종 다양성 및 연간발생 동태

장용석, 김수빈, 강성혁, 현승용, 김용근, 김종현, 정대천<sup>1</sup>, 김동순

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밀빠진벌레과(Nitidulidae)는 딱정벌레목(Coleoptera)에 속하는 곤충으로 감귤 수확기에 낙과하여 부패하는 과실에 발생하여 부패 과를 섭식하며 살아간다. 본 연구는 감귤과원에 발생하는 밀빠진벌레과의 종 다양성과 연중 발생 시기와 정도를 구명하고자 2009년 6월부터 2010년 5월까지 제주도 감귤원에서 밀빠진벌레과 발생 및 연간동태를 조사하였다. 낙과하여 부패하는 과실에서 채집한 밀빠진벌레과 성충을 분리 및 동정한 결과 8종으로 분류·동정 되었으며 이중 2종은 국내 미기록 종으로 동정되었다. 밀빠진벌레과 8종의 연간 발생에서 애넵적밀빠진벌레 종만 겨울에 다량 발생하였으며 나머지 7종은 초여름부터 초겨울까지 발생하였다. 밀빠진벌레과 8종에 대한 시기별 종 다양도 관련 지수의 변동에서 종수는 겨울철에 낮게 나타났으며, 종풍부도는 4월에 가장 높았고 1월 및 2월에 낮았다. Shannon지수는 12월과 1월 '0'값을 보였고 봄부터 가을까지 생육기에는 1.0에 근접하였다. Hill 지수는 겨울철 12월부터 2월까지 낮았고 생육기에는 2.5 부근에서 변동하였다. 종균등도는 겨울철인 12월과 1월에 '0'값을 나타냈고 생육기에는 0.8 정도 값을 보였다. 8종의 발생시기의 유사성을 기준으로 군락분석을 실시한 결과 유사도 거리 0.5 수준에서 4개 집단으로 분리되었으며, 전체적으로 보았을 때 애넵적밀빠진벌레는 단일 독립집단으로 구분되었다.

**검색어:** 밀빠진벌레, 애넵적밀빠진벌레, 감귤, 종다양도, 종풍부도, 군집분석

P098

## **Inhibition of feeding behaviors using acoustic stimuli in aphids: Electrical penetration graph analyses**

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Aphids feed on host plants by penetrating the stems or leaves with stylets. The feeding behavior of aphids consists of probing, penetration, salivation, and sap ingestion. To assess the effects of sound on feeding behavior, we monitored the stylet activity of the green peach aphid, *Myzus persicae* (Sulzer), using electrical penetration graph (EPG). The use of EPG was critical for determining the stage, frequency, and duration of feeding in aphids. We played back three acoustic stimuli of sine waves with frequencies of 100, 1000, and 5000 Hz to adult aphids. In the sound treatment group, the frequencies of probing, penetration, and salivation increased, whereas the duration of sap ingestion decreased. The results of EPG revealed that the acoustic stimuli may restrict aphid feeding by inhibiting sap ingestion.

**Key words:** aphid, *Myzus persicae*, EPG, behavior, sound stress, green peach aphid

## 중부지방 복숭아과원의 해충 발생실태 조사

전홍용, 김동순, 조명래, 양창열, 노일래, 정호정

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중부지방의 복숭아과원에서 발생하는 해충의 발생실태를 1999년부터 2008년까지 월동해충(2월 중하순), 생육초기(5월 중하순), 생육중기(7월 중하순), 생육후기(9월 중하순)로 나누어 조사를 수행하였다. 연도별 월동해충을 조사한 결과 뽕나무깍지벌레, 점박이응애, 나방류 유충, 진딧물류 등이 월동기 주요 해충으로 조사되었다. 월동해충 중에서 뽕나무깍지벌레는 한주에 5가지당 1.2('05)~3.7('00)마리, 점박이응애는 25cm<sup>2</sup> 당 0('00)~5.6('99)마리, 나방류 유충은 5주당 0('00)~1.9('02)마리, 진딧물류는 100눈당 알수가 0('00)~10.7('08)개였다. 복숭아 생육초기에서는 복숭아혹진딧물, 복숭아순나방, 복숭아굴나방, 복숭아유리나방, 점박이응애, 하늘소류, 뽕나무깍지벌레가 조사되었으며, 이 중에서 복숭아혹진딧물이 50개 신초당 0.5('99)~33.6('00)마리가 발생하여 발생밀도가 높았다. 생육중기에서는 점박이응애, 복숭아굴나방, 복숭아순나방, 복숭아혹진딧물, 복숭아심식나방, 복숭아유리나방, 하늘소류가 발생하고 있었으며, 이 중에서 점박이응애가 100엽당 5('08)~175.5('00)마리로 발생밀도가 가장 높았다. 중부지방의 복숭아는 다른 과종 보다 빨리 수확이 종료되어서 9월 중순 이후에는 지상부 해충의 조사가 이루어지지 않았다. 10년간의 조사결과를 종합하면 복숭아에서는 생육시기에 따라 해충의 다발생 종이 다르지만, 점박이응애, 복숭아혹진딧물, 복숭아유리나방 등이 해마다 발생되었으며 심식충류에 의한 과실피해는 높지 않았지만 해마다 발생하였다.

**검색어:** 복숭아, 뽕나무깍지벌레, 점박이응애, 복숭아혹진딧물, 복숭아유리나방

## Modeling adult emergence of *Osmia cornifrons* (Hymenoptera: Megachilidae) after overwintering diapause

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Pollinating insects function significantly in structuring ecosystem as well as agricultural production. Among the variety of pollinators, *Osmia cornifrons* is one of the important pollinators in apple orchards. Unlike honey bees, *O. cornifrons* is able to pollinate at low temperature that facilitates its wide commercial use. The female *O. cornifrons* in nature lay their eggs to the interior of the bamboo reeds where they spend their larval and pupal stage throughout the summer and during fall they overwinter as adult. The adult bee emerges from the overwintering cocoon in the spring seasons. Since the complete synchrony with flowering period is critical, farmers collect and store the dormant state of *O. cornifrons* in cold storage and expose them in due time to outdoor temperatures for their emergence, pollination activity can be performed. However, information on biological and ecological requirements for the emergence of overwintering adults are rarely reported. We carried out the experiments on temperature dependent adult emergence and constructed the emergence model based on developmental rate and distribution. Parameters were estimated from linear model and weibull function. Further validation in the field or semifield condition will be pursued.

**Key words:** pollination, *Osmia cornifrons*, overwintering cocoon, synchrony temperature dependent model, parameters



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## 단감 수출단지 단감 해충 발생 실태

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우리나라 5개 지역(전남 순천시, 경남 진주시, 경남 창원시, 경남 김해시, 울산 울주군) 단감수출 단지를 대상으로 검역대상 해충을 비롯한 발생 해충조사를 단감 생육 기간 중에 조사 하였다. 단감 수출단지에서 채집된 해충은 4목 16과 26속 26종 이었다. 그 중 장님노린재(*Lygocris spinolae*)와 톱다리개미허리노린재(*Riptortus clavatus*), 애모무늬잎말이나방(*Adoxophyes orana*), 복숭아명나방(*Dichocrocis punctiferalis*), 차잎말이나방(*Homona magnanima*), 담배거세미나방(*Spodoptera litura*) 이 모든 과수원에서 발견되었으며 김해 진영지역에서는 외래 유입종인 미국선녀벌레(*Metcalfa pruinosa*)의 흡즙에 의한 생육저하와 분비물에 의한 그을음 병 발생 피해가 확인되었다. 검역대상 해충으로는 감꼭지나방(*Stathmopoda masinissa*)이 9월 말에 울산지역의 한 과수원에서 유충 3마리가 확인 되었고, 7월 중순 김해 진영지역에서 성충 1마리만이 발견 되었다. 발생 해충의 종류나 밀도는 지역 간 보다 지역 내 과원 간 차이가 더 많았다.

**검색어:** 단감, 수출단지, 해충, 검역, 피해

## Damages by *Tyrophagus* spp. (Acari: Acaridae) in horticultural crops in Korea

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Damages by *Tyrophagus* spp. (Acari: Acaridae) on horticultural crops were newly observed in recent years especially in organic culture greenhouses in Korea. The crops damaged by the mite species were *Spinacia oleracea* L. (spinach), *Cucumis sativus* (cucumber), and *Phalaenopsis schilleriana* (orchid). The spinach inner leaf growth was halted affected by the feeding of *Tyrophagus similis* at the early stage of the shoot emergence. The young leaves of the spinach bud had small holes and the leaves were deformed as they grew up. The surface of young cucumber fruits became shiny and soft at the early damage stage and the damaged surfaces became corky as the plants grew up. The mite from cucumber was identified as *Tyrophagus neiswanderi* Johnston & Bruce. In phalaenopsis orchid, the flower buds became yellow and dropped and the lower side of the leaves had white spots. The damages were caused by *Tyrophagus putrescentiae*.

**Key words:** *Tyrophagus similis*, *Tyrophagus neiswanderi*, *Tyrophagus putrescentiae*, damage symptoms, Horticultural crops

## Community Structure of Ground Beetles (Coleoptera: Carabidae) in the Reclaimed Land, Korea

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Community structure of ground beetles in Seokmun- and Siwha-reclaimed lands was investigated with pitfall traps from 21 May to 1 November, 2010. Survey areas were divided by the status of reclamation, vegetation, and flooding frequency. Status of the Seokmun-reclaimed land in Chungcheongnam-do is the progress of conversion to rice paddy after completion, and then dominant plant is *Secale cereals*. For the Siwha reclaimed land in Gyeonggi-do, reclamation is ongoing, and thus *Imperata cylindrica* and *Calamagrostis pigeios* are dominant plants. Flooding was more frequent in Seokmun than in Siwha as 4 times and none, respectively. A total of 3,352 epigeic insects of 9 orders and 22,981 epigeic insects of 9 orders were collected from the Seokmun- and Siwha-reclaimed land, respectively. Collembola was the most abundant in each site. In ground beetle assemblage, 11 species belonging to 7 subfamilies Seokmun and 8 species belonging to 5 subfamilies in Siwha were identified from 183 and 101 collected ground beetles. *Chlaenius pallipes* (107 individuals, 58.5%) and *Pheropsophus javanus* (52 individuals, 28.4%) was dominant in Seokmun, while *Harplus jureceki* (37 individuals, 36.6%), *Synuchus arcuaticollis* (17 individuals, 16.8%), and *Dolichus halensis halensis* (17 individuals, 16.8%) was dominant in Siwha. The Shannon's index value was 1.147 and 1.671 in Seokmun and Siwha, respectively. Similarity by the Sørensen index between Seokmun and Siwha was 0.3158. In conclusion, community structure and seasonality of ground beetles were significantly different between two reclaimed lands, and this difference appears to be due to their different habitat conditions such as flooding frequency and progress of reclamation.

**Key words:** epigeic insects, ground beetles, community structure, reclaimed land

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## 톱다리개미허리노린재에 대해 항생성을 보이는 콩과 유전자원 선발

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톱다리개미허리노린재(*Riptortus pedestris*)(호리허리노린재과)는 주로 콩과 식물을 기주로 삼고, 재배콩에 심각한 피해를 주는 해충이다. 이 해충에 대해 항생성을 갖는 유전자원을 찾기 위해, 수년에 걸쳐 약 천점의 콩과 유전자원을 검토하였고 여기 그 결과를 보고한다. 항생성 정도는 마른 종자 혹은 식물체 상태로 꼬투리를 톱다리개미허리노린재에 섭식시켜 생존율을 관찰하거나 꼬투리의 피해 정도로 판정하였다. 재배콩(*Glycine max*) 약 60여 품종과 돌콩(*G. soja*) 약 600여점으로 부터는 항생성을 지닌 유전자원이 발견되지 않았다. 미국이나 아르헨티나로부터 도입된 노린재과 해충에 대해 저항성이 있다고 보고된 자원들도 역시 본 해충에 대해 항생성을 보이지 않았다. 기타 *Glycine*속 다른 종 약 80여 유전자원들에서 일부 항생성을 보이는 자원이 발견되었다. 한편 *Vigna*속 식물들 중에서 여우새팥(*V. nakashimae*)의 약 120점이 조사되었는데 대부분 실험곤충에 대해 매우 강한 항생성을 나타내었다. *Vigna*속 다른 종 약 60여점에서 항생성을 보인 일부 유전자원이 선별되었다. *Phaseolus*속과 *Cajanus*속 약 20여 유전자원에서도 항생성이 보이는 몇 자원이 선별되었다.

**검색어:** 톱다리개미허리노린재, 콩과 유전자원, 항생성, 선발

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## 배에서 깍지벌레류 기생벌레에 의한 기생율과 온실가루깍지벌레 암컷의 온도별 각태의 기간

조영식, 송장훈, 박장현, 이한찬

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전남 나주시 배시험장에서 채집한 깍지벌레류에서 채집한 깍지벌레류에서 기생벌레에 기생된 비율을 조사한 결과, 전체 조사한 깍지벌레류에 대한 기생율은 25.8%였다. 1월의 기생율이 높은 것은 이전에 기생당한 깍지벌레가 발견된 원인으로 생각된다. 한편, 배나무에서 채집한 온실가루깍지벌레(*Planococcus kraunhiae*)를 잠두(*Vicia faba* L.) 유묘에서 사육하면서 15, 20, 25, 30°C에서 각태별 발육기간을 조사하였다. 15°C에 알기간은 약 20.9일이었고 25, 30°C에서 7.1, 7.5일이었다. 알에서 성충까지 전체 기간은 15°C에서 약 117.7일이었고, 20, 25, 30°C에서 각각 54.9, 32.4, 30.3일이 소요되었다. 산란전 기간은 각각 31.6, 17.2, 13.1, 16.8일이 소요되었다.

검색어: *Planococcus kraunhiae*, 기생률, 배나무, 발육기간, *Vicia faba*

## Species abundance distribution of aquatic insects presenting ecological integrity in lakes

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Structural property in communities of aquatic insects and benthic macroinvertebrates could reflect the impact of environment on aquatic ecosystems. Benthic macroinvertebrates were collected at 18 different lakes across different levels of environmental impact in Korea. Community responses were analyzed by species abundance distribution (SAD). Rank-abundance (or relative abundance) curves were evaluated by classical SAD (Geometric series, Log-series, and Lognormal distribution) and niche apportionment models (dominance pre-emption, random assortment, random fraction, and dominance decay). Geometric series was more accepted in lakes among classical SAD models. Niche apportionment models were observed in a diverse manner across different level of ecological integrity in lakes. Dominance decay model and random fraction model were frequently fitted to the lakes with higher integrity, while dominance pre-emption and random assortment models tend to be presented in low to middle range in integrity.

**Key words:** Benthic macroinvertebrate, Species abundance distribution, Ecological integrity, Niche apportionment model.

## 목재 부후균이 흰개미의 서식에 미치는 영향

조창욱, 김영희, 홍진영, 정미화, 김수지, 최정은

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백색부후균(*Trametes versicolor*)과 갈색부후균(*Tyromyces palustris*)은 목조 문화재 및 건축물 등의 목재 조직의 건조, 부패와 균열, 스펀지화, 변색 등 다양한 손상을 발생시켜 구조적 또는 미학적인 관점에서 심각한 문제를 나타내고 있다. 그리고 가장 피해를 많이 주는 해충인 흰개미 (*Reticulitermes speratus* Morimoto)는 목조 건축물의 옥의 기둥이나 대들보 등의 표면을 얇게 남겨 두고, 내부는 격렬히 먹어 들어가 공동화시켜, 결국은 속이 빈 기둥이 되어 건축물이 무너져버리는 피해를 줄 수 있다. 대표적 피해 미생물과 곤충인 두 종의 부후균이 흰개미의 서식에 미치는 영향을 파악하기 위하여 부후균이 만연된 곳에 흰개미를 넣어 공존의 가능성을 실험해 보았다.

페트리디쉬에 한 달간 두 종의 부후균을 배양한 후 각각 병정개미 5마리, 일개미 45마리씩 넣고, 흰개미의 섭식을 위한 목재 시편을 넣었다. 일주일 간격으로 관찰하여 총 12주 동안 실험을 진행하여 총질량 감소, 실험 전, 후 목재 질량 감소를 측정하였다.

전반적인 총질량은 두 종류의 부후균에서 다 감소하였다. 목재의 질량은 백색부후균에서는 모두 감소하였으나 갈색부후균에서는 오히려 질량이 증가한 경향을 볼 수 있었다. 그리고 섭식량을 측정하기 위한 목재의 건조 후 질량에서는 갈색부후균에 넣었던 목재의 질량 감소가 더 많았던 것을 알 수 있었다. 결과적으로 갈색부후균이 목재를 더 부후시켜 습하게 만들어 흰개미 섭식에 도움을 주는 것을 알 수 있었고, 갈색부후균과 흰개미가 목조 건축물에 함께 피해를 줄 때 더 큰 피해를 줄 것으로 사료된다.

**검색어:** 갈색부후균, 백색부후균, 흰개미, 목조문화재

## 평화의 댐 증축공사후 나타나는 저서성대형무척추동물상

주영돈, 레수안비, 치무지에, 울지자르갈, 박보선, 배양섭

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평화의 댐은 높이 125m, 길이 601m, 저수량 2,630,000,000m<sup>3</sup>로 강원도 화천에 위치하고 있으며 2006년 6월 15일 2차 증축공사를 준공 하였다. 하천에 댐을 건설하게 되면 유수역이던 지역의 유속이 급격히 감소하고, 수위 상승 및 그에 따른 수변의 확장으로 인해 인공적인 정수역으로 변화하게 된다. 따라서 유수역에 적응하여 살아가던 저서성대형무척추동물들은 물의 흐름이 있는 상류지역 등 주변지역으로 이동하거나, 그러지 못한 개체는 사멸하게 되고, 새로이 정수역이 된 지역은 환경에 맞는 종들로 구성원이 대체된다. 이러한 일련의 변화과정은 댐이 건설된 지역 뿐 아니라 그 주변 지류에도 영향을 줄 수 있으며, 조사지역인 평화의 댐 주변은 그러한 변화과정이 진행되고 있는 불안정한 생태계로 볼 수 있다. 본 연구는 평화의 댐 주변 지역 4개 지점 및 대조군에 대해 2006, 2008, 2010년에 걸쳐 연 2회 조사수행 후 저서성대형무척추동물의 군집구조를 분석하였다. 비교 결과 지속적으로 종수 및 개체수가 늘어나고 있었으며, 특히 유수역에서의 개체수 증가가 두드러지게 나타났다. 반면 정수역은 종수가 줄어들고 우점도가 증가하는 양상을 나타내어 적절한 서식지가 형성되지 못하고 있는 것으로 나타났다.

**검색어:** 평화의 댐, 저서성대형무척추동물, 군집분석



## 한국산 재주나방과(Lepidoptera: Notodontidae) 유충 17종에 대한 형태적, 생태적 특징 기재

지은미, 우건석<sup>1</sup>, 권건형, 김경환, 권영대

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재주나방과(Notodontidae)는 중형 크기의 나방으로 전 세계적으로 약 2,500종 이상이 알려져 있으며, 국내에는 현재까지 104종이 기록되어 있다(Park & Kwon, 2010). 재주나방과 유충 가운데 일부 종들은 농업·산림해충으로서 이들에 대한 생활사나 기주식물에 대한 정보는 잘 알려져 있으나, 주요해충이 아닌 종들에 대한 정보는 부족한 실정이며, 대부분이 외국의 자료를 인용하고 있다.

따라서, 본 연구소에서 산림해충의 조기 진단을 위한 연구의 일환으로 2009년부터 2010년까지 2년간 나비목 분류군 전반에 걸친 유충 사육 결과 재주나방과에서 29종이 사육되었다. 이 가운데 17종이 동정되었으며, 특히 먹점재주나방 유충의 출현시기와 기주식물은 국내에서는 처음으로 확인되었다. 그리고 검은띠나무결재주나방 외 4종의 기주식물이 국내에서 밝혀진 기록 외에 추가되었다. 이에 따라 동정된 재주나방과 유충 17종의 형태적 특징과 발생시기, 월동태, 기주식물 등 생태에 관한 정보를 기재한다.

**검색어:** 나비목, 재주나방과 유충, 기주식물, 발생시기, 월동태

## 제주도 열대과수 해충 종류 및 피해

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제주도에서 현재 망고(mango; *Mangifera indica* L. var. *irwin*), 용과(dragon fruit; *Hylocereus undatus*), 아떼모야(attemoya) 순으로 많이 재배되고 있다. 2008년부터 2010년까지 제주도에 재배되는 망고에는 총 13종의 해충이 발생하는 것으로 조사되었고, 이중 볼록총채벌레(*Scirtothrips dosalis*), 오이총채벌레(*Thrips palmi*), 차면지응애(*Polyphagotarsonemus latus*), 담배거세미나방(*Spodoptera litura*), 차애모무늬이말이나방(*Adoxophyes spp.*), 네눈썹가지나방(*Ascotis selenaria*) 등 나방류 해충의 발생과 피해가 많다. 특히, 볼록총채벌레는 2010년에 처음으로 망고에 발생하여 피해를 주는 것으로 확인되었고, 잎 외에도 과실 표면을 가해하여 상품성을 크게 낮추어 경제적 피해를 유발하였다. 용과에서는 개미(formicidae), 목화진딧물(*Aphis gossypii*) 등 진딧물류, 담배거세미나방(*Spodoptera litura*), 달팽이류의 발생과 피해가 많았다. 특히 용과 재배 전시기에 걸쳐 개미에 의한 줄기 및 과실 피해가 가장 심했다. 아떼모야의 경우 담배거세미나방(*Spodoptera litura*), 차잎말이나방(*Homona magnanima*), 진딧물류, 감굴바구미(*Sympiezomias lewisi*)가 발생하였다.

**검색어:** 열대과수, 망고, 용과, 아떼모야, 해충, 피해

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## Efficiency comparison by three control methods against *Dichocrocis punctiferalis* (Lepidoptera: Pyralidae) at chestnut orchards

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The the peach pyralid moth, *Dichocrocis punctiferalis* causes the most serious damage to chestnut in Korea. This study was conducted to compare the efficiency of control with aerial spraying(AS350-B2 Helicopter, 15m/flight altitude, Nozzle-orifice D6, Fenitrothion EC 50% 1 L /ha), sex pheromone trap(25 Wing traps/ha, 75:25 mixture of (*E*)-10-hexadecenyl aldehyde (*E*10-16:Al) and (*Z*)-10-hexadecenyl aldehyde, 1mg/trap), and crown spraying(BF530, Fenitrothion EC 50% 1 L /ha) against *D. punctiferalis* at chestnut orchards. After chestnut harvest in Autumn, the damaged rate(%) by *D. punctiferalis* showed 29.6±1.7 in aerial spraying, 27.8±8.4 in sex pheromone trap, and 8.9±3.8 in crown spraying, respectively. The crown spraying showed the highest control effect among the 3 control methods. The other methods were similarly effective.

**Key words:** *Dichocrocis punctiferalis*, Chestnut orchard, Aerial spraying, Sex pheromone trap, Crown spraying.

## 고추 유기재배시 피복재료에 따른 곤충상 변화

한은정, 박종호, 홍성준, 김용기, 지형진

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본 연구는 고추 유기재배지 토양 피복에 따른 곤충상의 변화를 비교하고자 수행되었다. 충남 홍성과 충북 단양의 6농가 14개 고추밭에서 총 4회 조사되었으며 시험 처리구는 비닐피복, 종이피복, 볏짚피복, 초생재배이며, 각 처리는 고추 고랑에 3반복으로 처리되었다. 처리구 내에서 반복 당 3지점을 임의로 선정하여 동력 흡충기(12V)를 이용하여 지상부에 존재하는 곤충을 채집하였다. 채집된 곤충은 현미경하에서 동정되었으며, Primer 6 프로그램을 이용하여 종 다양도지수를 분석하였다. 조사 결과 4회에 걸쳐 총 3064개체의 곤충 및 거미가 채집되었으며, 진딧물이 포함되어 있는 매미목과 천적인 거미, 벌류가 주로 채집되었다. 조사 기간 동안 처리구별 종풍부도지수(Magalef index)는 비닐피복처리구(1.69, 1.49, 2.86, 3.64)에 비교하여 초생재배(2.78, 2.58, 4.40), 볏짚피복(3.90, 4.63, 3.13, 3.23), 종이피복처리구(3.36, 3.23, 3.23, 3.46)에서 전반적으로 높게 나타났으며, 종다양성 지수(Shannon index) 역시 비슷한 경향을 보였다. 채집된 곤충 중 천적군에 대한 해충군의 비율을 계산한 결과, 초생재배처리와 볏짚피복처리구와 같이 생물자원을 피복한 경우 비닐 및 종이로 잡초를 완전히 제거한 농가에 비교하여 천적 대비 해충의 비율이 유의하게 낮은 것으로 조사되었다.

**검색어:** 유기농업, 고추, 곤충상

## 제주도내 작물 재배지에서의 볼록 총채벌레 월동 양상

황록연, 이평호, 오승협, 현재욱

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제주도내에서 점차 문제가 되고 있는 볼록총채벌레의 주요 월동처와 월동 양상을 조사 하였다. 볼록총채벌레의 월동처는 잎, 가지, 식물의 잔재물, 흙 등으로 감귤과 키위 등 그 기주 식물과 온도, 습도 등의 환경에 따라 다양한 것으로 알려져 있다. 제주도에서 조사한 결과 겨울철 볼록총채벌레가 기주 식물의 가지와 잎에서는 관찰되지 않아 식물의 잔재물과 흙을 일정량 채취하여 35×45×8cm의 검은종묘상자에 넣은 후 같은 크기의 밀판을 자른 종묘상자를 뒤집어 위에 덮고 끈끈이 트랩이 부착된 미세한 크기의 구멍이 난 필름을 덮었다. 이상자를 온도 25℃, 습도 30%의 생육실에 놓고 상자안의 트랩에 붙는 볼록총채벌레의 수를 조사하였다. 식물잔재물과 흙을 채취한 곳은 비가림 시설내의 키위포장 1곳, 노지 녹차밭 1곳, 가온시설내의 한라봉 포장 1곳, 가온시설내의 천혜향 포장 1곳, 노지온주밀감 포장 2곳 총 6곳의 식물잔재물 1kg 1반복과 흙3kg 3반복을 조사하였다. 12월 20일부터 1개월 간격으로 3월 20일까지 4차례에 걸쳐 식물잔재물과 흙을 채취 하고 2~5일 간격으로 성충이 더 이상 나오지 않는 시기까지 조사 하였다. 그 결과 비가림 시설내의 키위포장에서 총 471마리로 다른포장(시설 한라봉 82마리, 노지온주밀감(상신레리) 73마리, 녹차밭 19마리, 시설 천혜향 5마리, 노지온주밀감(위미리) 4마리)에 비해 많은 볼록총채벌레를 관찰 할 수 있었다. 12월에 채취한 것에서 227마리, 1월 184마리, 2월 238마리, 3월 5마리가 관찰 되었다. 볼록총채벌레가 가장 많이 채집된 키위포장에서 볼록총채벌레의 발생비율은 식물잔재물 95%와 흙 5%로 나타났다. 키위포장에서 보면 12월에 채취된 식물잔재물과 흙에서는 생육실에 넣은후 10일후에 1월에 채취된 것에서는 8일후 그리고 2월에 채취된 것에서는 5일, 3월에 채취된 것에서는 3일후에 가장 높은 밀도를 보였다.

**검색어:** 볼록총채벌레, 월동처, 월동, 휴면

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## Molecular and biochemical properties of venom allergen-like protein support a pathogenic function in the pinewood nematode, *Bursaphelenchus xylophilus*

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Venom allergen-like protein 2 (Vap2) was characterized from the pinewood nematode, *Bursaphelenchus xylophilus*, which is a destructive pathogen in several countries including Japan, China and Korea. Among three *vaps* of *B. xylophilus* (*Bx-vap*) reported in GenBank, *Bx-vap2* showed the highest transcript level in both pine-grown propagative stage (PGPS) and media-grown propagative stage (MGPS). *Bx-vap2* also was revealed that its transcript level over 10-fold increased in PGPS. In addition, western blot using BxVap2-polyclonal antibody showed that expression level of BxVap2 was significantly increased in PGPS. In immunohistochemistry, moreover, strong signals were detected around putative subventral gland in PGPS, whereas weak signals were observed in MGPS. These experimental results suppose pathogenic function of BxVap2 and migration assay using *Bx-vap2* knock-down worms by RNA interference supports this postulation.

**Key words:** venom allergen-like protein, *Bursaphelenchus xylophilus*, transcription level, immunohistochemistry, pathogenicity, RNA interference

## 소나무재선충병 피해위험도 분석

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소나무재선충병 피해위험도 평가를 위하여 소나무 임분 20개소 140개 plot에서 임황, 지황, 피해상황 등을 조사하여 피해양상을 분석하였다. 전국규모 등 넓은 규모에서는 지역적 연평균기온, 매개충의 분포, 소나무류의 분포 등이 중요한 인자이며, 임분수준에서는 고도, 경사도, 방위 임상조건 등이 중요한 인자였다. 감염목 수는 고도가 높아짐에 따라 크게 감소( $r=-0.34, p<0.05$ )하였으며, 반면 경사도와는 양의 상관관계( $r=0.51, p<0.01$ )를 보였다. 방위 또한 높은 상관성을 보였다( $r=0.60, p<0.01$ ). 임상은 음의 상관관계를 보였다( $r=-0.28, p<0.05$ ). 그러나 경급, 영급 등은 유의한 상관성이 없었다( $p<0.05$ ). 한편 감염률은 경사도, 방위, 경급, 영급에 의해 영향을 받았으며, 감염목 수와 감염률이 다소 다르게 분석되었다. 또한 단목수준에서는 흉고직경이 큰 나무가 피해를 많이 받으며, 단목의 수세에 따라 크게 영향을 받았다. 건전목의 흉고직경과 벌근 직경은 매우 높은 상관성을 보였으며 ( $R^2=0.93\sim 0.95$ ) 수종에 따라 다소 차이는 있었으나 유사한 값을 보였다. 이를 이용하여 피해목의 벌근직경에 따라 흉고직경을 산출하였다. 수종에 따라 피해목과 건전목의 흉고직경을 비교한 결과 소나무 및 해송 모두 소나무재선충 비감염목 보다는 감염목의 흉고직경이 매우 컸다

**검색어:** 소나무재선충, 피해위험도, 임황, 감염율, 임분수준, 매개충

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**Effect of Diameter and Paraffin Sealing of Twig and Dosage of Pine Wood Nematode on Reproduction of Pine Wood Nematode, *Bursaphelenchus xylophilus* (Nematoda: Aphelenchoididae)**

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Pine wood nematode (PWN), *Bursaphelenchus xylophilus* is associated with the pine wilt disease and transmitted by pine sawyer, *Monochamus alternatus*. Because pine sawyer has one-year life cycle, one natural infection of PWN is occurred a year. Therefore, artificial propagation method of PWN is needed to improve experiment associated with PWN. In this study, effect of diameter, paraffin sealing of twig and dosage on pine wood nematode reproduction in Japanese black pine, *Pinus thunbergii*. PWN reproduction was compared in twigs of *P. thunbergii* and *P. densiflora*. Numbers of reproduced PWN were higher with decreasing diameter of twig. Distance (5 and 10 cm) from inoculation site of PWN did not influence reproduction of PWN. Reproduced numbers of PWN were higher in the paraffin-sealing twig than non-sealing twig. Dosage of PWN influenced reproduction of PWN. Reproduction rate was the highest at the rate of 10 IJs (13.7 and 61.1-fold increasing in *P. densiflora* and *P. thunbergii*, respectively 30 days later) whereas lowest at the rate of 1000 Ijs (1.1 and 0.7-fold increasing in *P. densiflora* and *P. thunbergii*, respectively 30 days later). Numbers of reproduced PWN were more in *P. thunbergii* than *P. densiflora*.

**Key words:** *Bursaphelenchus xylophilus*, reproduction, diameter, pine tree, inoculation



## Ovarian development and oviposition response of two vectors of pine wood nematode, *M. alternatus* and *M. saltuarius*

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The ovarian development and oviposition response of two vector beetles of pine wood nematode, *Monochamus alternatus* and *M. saltuarius*, was investigated. The ovary structure of two beetles was investigated by means of light microscopy. The ovary of both beetles was composed of two ovaries that are connected by a common oviduct. Each of the two ovaries was consisted of twelve ovarioles, the functional units of female oogenesis. The ovary type was meroistic telotrophic with nurse cells and oocytes in the tropharium. Ovarian development of two vector beetles was completed at 12-14 days after maturation-feeding pine twigs. Aspect of accumulation of vitellogenins in the ovary of two vectors showed difference in developmental stages and major yolk proteins, differently from vitellogenin. To investigate oviposition performance of two vector beetles, we provided *P. thunbergii* and *P. koraiensis* bolts for egg laying and collected emerged adults from each pine bolts in the next year. *M. saltuarius* females made more oviposition wounds and entrance hole of larvae than *M. alternatus* on pine bolts. We also investigated whether two beetles can transmission of *Bursaphelenchus xylophilus* and the European type of *B. mucronatus* via oviposition to non-infected dead pines. 48-83% from newly emerged adults of two beetles were carried two species nematode. This results suggested that two species beetles can transmit nematodes through oviposition performance and transmitted nematodes successfully propagate in non-infected dead pines.

**Key words:** pine wood nematode, *Monochamus alternatus*, *M. saltuarius*, ovarian development, *Bursaphelenchus xylophilus*, *B. mucronatus*, oviposition

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## Repellency of Plant Essential Oils against *Aedes aegypti* (Culicidae: Diptera)

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The repellency of 104 plant essential oils to female *Aedes aegypti* was examined using a cage-distribution assay. Results were compared with those of the conventional mosquito repellent N,N-diethyl-m-toluamide (DEET). Coriander, oreganum, pennyroyal, lemon eucalyptus, and spearmint exhibited high repellency effect (>60 minutes at 50 mg/filter paper), followed by sage, lavender, tarragon, bergamot, and neroli oils which showed moderate effective (< 40 minutes at 50 mg/filter paper (5 cm diameter)). In the light of global efforts to reduce the level of highly toxic synthetic repellents, essential oils described merit further study as potential repellents for the control of mosquito populations.

**Key words:** Botanical repellents; *Aedes aegypti*; essential oil

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## Study on solid-state conditions and growth characteristics of *Paecilomyces lilacinus* HY-4

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*Paecilomyces lilacinus* HY-4 is an entomopathogenic filamentous fungus that has exhibited insecticidal activity against *Adoretus tenuimaculatus* and *Tetranychus urticae*. Strain HY-4 has attracted a great deal of industrial concerns because this organism can be applicable as a potent bio-pesticide. In this study, we developed an optimal diphasic fermentation technique for HY-4 conidial production. The substrate prescription which was made up of hulls or brans was obtained by screening of agricultural products, and the conidial production could reach a minimum of  $2.5 \times 10^{10}$  conidia/g after solid fermentation for 12 days in a given condition. It was interesting to note that strain HY-4 was propitious to sporulate more efficiently and productively in liquid fermentation process in the presence of insect pupa. For the industrial application of the HY-4 spores, their pH and thermal stabilities were evaluated on SDA agar plate as well. Additionally, the germination rate of HY-4 spores was still above 90% even when they were stored for 5 months at ambient temperature.

**Key words:** *Paecilomyces lilacinus*, substrate optimization, biological control, entomopathogenic fungi, solid-state fermentation

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## Bistrifluron과 Etofenprox 혼합 유현탁제(SE)의 복숭아순나방과 복숭아심식나방에 대한 방제효과

강명기, 김시용, 김영권, 엄정국, 정훈성, 김태준

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Bistrifluron은 IGR계 살충제이며 나비목 해충의 알에 대한 부화억제 및 유충 생육단계에서 Chitin 생합성을 저해하여 치사시킨다. Etofenprox는 합성 Pyrethroid계통 살충제이며 곤충의 신경세포에 영향을 미치며 이온통로를 교란시켜 곤충을 치사시킴으로서 살충활성이 빠르게 나타난다.

본 연구는 사과, 복숭아, 자두 등의 과원에서 신초 및 과실을 직접 가해하여 생산량 및 품질저하에 큰 영향을 미치는 복숭아순나방(*Grapholita molesta*)과 복숭아심식나방(*Carposina sasakii*)에 대하여 다른 작용기작을 이용한 혼합 살충제 Bistrifluron+Etofenprox 25% SE의 방제효과를 확인하고자 수행하였다. 경북지역의 사과와 자두 과원에서 페로몬트랩을 이용하여 복숭아순나방과 복숭아심식나방의 1세대 성충 다발생기를 확인하였다. 복숭아순나방을 대상으로 성충 다발생기부터 7일 간격으로 2회 경엽처리하였고, 최종약제처리 8일과 18일 후 피해 신초를 조사하였다. 복숭아심식나방을 대상으로 성충 발생초기부터 10일 간격으로 3회 경엽처리하였고, 최종약제처리 9일 후 피해과수를 조사하였다. Bistrifluron+Etofenprox SE는 복숭아순나방에 대하여 사과 과원에서 100%와 92.5%의 방제효과를 확인하였고, 자두 과원에서 100%의 우수한 방제효과를 확인하였다. 복숭아심식나방에 대하여 자두 과원에서 84%의 방제효과를 확인하였다.

본 연구결과 Bistrifluron+Etofenprox SE는 복숭아순나방과 복숭아심식나방의 방제약제로 활용될 수 있을 것이다.

**검색어:** Bistrifluron, Etofenprox, 복숭아순나방, 복숭아심식나방

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## Pyrifluquinazon nano type에 대한 복숭아혹진딧물 (*Myzus persicae*)의 섭식행동과 살충효과

강민아, 윤규식, 권혜리, 박민우, 조신혁, 신호섭, 김세희,  
서미자, 유용만, 윤영남

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Pyrifluquinazon은 새로운 생물학적 활성 모형을 기초로 만들어진 화학합성 살충제이다. 이 살충제의 작용기작은 곤충의 행동을 변형시켜 섭식을 하지 못하게 함으로서 굶어 죽게 하는 것으로 알려져 있다. 본 실험에서는 pyrifluquinazon의 완효형 제형을 만들어 복숭아혹진딧물에 대한 섭식행동과 살충효과를 검증하였다. pyrifluquinazon nano type은 코팅할 때 사용되는 키토산 용액의 분자량과 농도에 따라 CS 30,000 0.1%, CS 3,000 0.3%로 제조하여 완효형 제형으로 사용하였고 원제형태의 pyrifluquinazon을 대조구로 사용하였다. 또한, EPG를 이용하여 이 약제에 대한 생물검정과 섭식행동 결과를 비교하였다. CS 30,000 0.1%를 추천농도(50ppm)로 처리했을 때 진딧물 살충효과와 증가율은 약제 처리 초기에는 저조하였지만 6일 후부터 점차 증가하였고, 처리 8일 후에 살충율이 가장 높았다. CS 3,000 0.3%의 경우, 처리 18일 후에 살충율이 71.7%를 나타냈고, 증가율은 -0.43으로 효과적인 완효형 제형의 결과를 보였다. 또한, 두 가지 nano type을 각각의 농도(25, 50, 100ppm)로 처리함에 따라, 복숭아혹진딧물에 대한 완효형 제형의 특성과 살충효과를 관찰한 결과, CS 30,000 0.1% 타입의 생물검정 결과, 다른 농도에서 보다 100ppm으로 처리한 경우 약제 처리 후 모든 일차에서 가장 효과적으로 증가율 저해가 관찰되었고, CS 3,000 0.3%를 100ppm으로 처리한 경우 약제 처리 18일 후에 살충율이 68.3%로 가장 높았다. 25, 50ppm의 농도로 희석된 2가지 nano 타입과 원제 형태의 제형에 대한 복숭아혹진딧물의 생물검정과 섭식행동을 비교하기 위해서 EPG를 수행한 결과, 25, 50ppm 모두 원제 형태의 제형의 경우 섭식 억제 효과가 약제 처리 2일 후에 가장 좋았지만, CS 30,000 0.1%는 25ppm에서 처리 8일 후, 50ppm에서 처리 14일 후, CS 3,000 0.3%의 경우 25ppm에서 처리 28일 후, 50ppm에서 처리 14일 후에 섭식억제 효과가 가장 우수하였다. 또한, 25ppm의 CS 3,000 0.3%에서 처리 12일부터 30일 까지, 50ppm에서는 처리 14일부터 30일까지 reaction time이 관찰되어 CS 3,000 0.3%가 가장 효과적인 완효형 제형의 특징을 나타내었다.

검색어: 복숭아혹진딧물, pyrifluquinazon, nano type, 완효형 제형, EPG

## **Insecticidal activity of *Monochamus alternatus* adults by trunk injection of systemic insecticides**

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Trunk injection of nematicides was applied to prevent pine wilt disease (PWD). Although the trunk injection of nematicides was effective to PWD prevention, it was not effective to a vector, *Monochamus alternatus*. Thus, This study was investigated for the insecticidal activity and the effect of oviposition deterrence by injecting to pine trees with systemic insecticides such as Acetamiprid SC 10%, Imidacloprid DC (20%), and Thiamethoxam DC (15%).

As a results, mortality of *M. alternatus* adults was 100% at 56 days after trunk injection. Percentage of *M. alternatus* adults moved to a young black pine tree by trunk injection of Imidacloprid DC (20%) and Thiamethoxam DC (15%) in screen cage (4.0×2.0×2.5m) was 76.7% and 70.0%, respectively. But the mortality of *M. alternatus* adults showed 100%.

Percentage of *M. alternatus* adults moved to the treated and untreated young black pine trees by trunk injection of Acetamiprid SC (10%) in screen cage (4.0×2.0×2.5m) were 25.9% and 49.5% at 1st day and 3rd day after treatment, respectively. Percentage of *M. alternatus* adults oviposited to treated pine logs at 3month after trunk injection of liquid mixture of Acetamiprid SC (10%) and Emamectin benzoate EC (2.15%) in screen cage (72×72×100cm) was 25%. But, untreated pine logs was 100%

**Key words:** Pine wilt disease, *Monochamus alternatus*, Trunk injection, systemic insecticide

## 복숭아원 복숭아순나방 교미교란제 처리에 의한 방제효과

김산영, 김임수, 김대홍, 박원흠, 이숙희

경북농업기술원 청도복숭아시험장

경북지역의 복숭아 주산지인 청도군, 영천시, 경산시 지역을 대상으로 2008년~2010년 동안 복숭아순나방 성페로몬을 이용하여 예찰하고, 이에 근거하여 복숭아순나방 피해 과원에 대해 교미교란제의 효과를 검토하였다.

페로몬트랩의 조사는 10일간격으로 하였으며, 설치된 루어의 교체는 약 6주 간격으로 하였다. 복숭아순나방 방제를 위한 교미교란제의 설치는 도포형을 사용하였으며 도포량은 120g/10a을 도포하였으며, 과원내부에 비해 가장자리에 20% 정도를 많게 하였다.

복숭아 과원의 복숭아순나방 1화기 평균 발생최성기는 2010년에 5월상순으로 2008년보다 10일정도 2009에 비해 20일정도 각각 늦어졌고, 발생밀도도 해에 따라 편차를 보였다.

교미교란제를 활용한 복숭아순나방 방제효과의 경우 성페로몬 예찰을 통한 성충유살수 조사에서는 교미교란제 처리 효과가 뚜렷하였으나, 피해순율과 피해과율 조사에서는 교미교란제의 처리방식에 따라 차이를 보였다. 주위에 복숭아 및 사과 등 복숭아순나방이 발생하는 과원이 인접해있는 곳에서는 효과가 떨어졌으며, 독립된 과원이나 교미교란제를 대면적에 처리했을 경우 피해순율이 3% 정도, 피해과율이 0.4% 정도로 방제효과가 높았다.

살충제 약제살포 횟수에서는 교미교란제 처리구에서 살충제 살포 횟수가 2회정도 절감되었다.

**검색어:** 복숭아순나방, *Grapholita molesta*, 페로몬, 교미교란제, 방제

## Larvicidal and Antifeeding Activities of Medicinal Plant Extracts against *Spodoptera exigua*

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The methanol extracts and essential oils from 9 medicinal plants, *Ulmus davidiana* var. *japonica*, *Cryptomeria japonica*, *Hedera rhombea*, *Prunus mume*, *Taxus cuspidatal*, *Paulownia coreana*, *Kalopanax pictus*, *Paris verticillata*, and *Ixeris dentata* were tested for their insecticidal activity against larvae of *S. exigua* by topical application method. And the methanol extracts and essential oils obtained from *Paris verticillata* and *Ixeris dentata* were subjected to a screening test for their antifeeding activities and pupation and adult emergence of *S. exigua* by a leaf-dipping method at a concentration of LC<sub>50</sub> value. The methanol extract from the bark of *C. japonica*, the leaf of *H. rhombea* and all parts of *P. verticillata* exhibited potent activity with LC<sub>50</sub> of 5.02, 4.21 and 5.46(g/L) 5days after treatment, respectively. But all of the essential oils except for *I. dentata* with LC<sub>50</sub> of 4.92(g/L) had shown high potential insecticidal activity compared to the methanol extracts against *S. exigua*. And the essential oil from all parts of *P. verticillata* and *I. dentata* have shown stronger antifeeding activity than those of methanol extracts against larvae of *S. exigua*. Also, the methanol extract and essential oil of *P. verticillata* and *I. dentata* affected growth pattern showing those of 32.5%, 10.0% of pupation and 27.5%, 10.0% of adult emergence of *S. exigua*.

**Key words:** *Spodoptera exigua*, antifeeding activity, methanol extract, essential oil



## Larvicidal and Antifeeding Activities of Medicinal Plant Extracts against *Plutella xylostella* L.

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The methanol extracts and essential oils from 9 medicinal plants, *Ulmus davidiana* var. *japonica*, *Cryptomeria japonica*, *Hedera rhombea*, *Prunus mume*, *Taxus cuspidata*, *Paulownia coreana*, *Kalopanax pictus*, *Paris verticillata*, and *Ixeris dentata* were tested for their insecticidal activity against larvae of *P. xylostella* by topical application method. And the methanol extracts and essential oils obtained from *Paris verticillata* and *Ixeris dentata* were subjected to a screening test for their antifeeding activities, pupation and adult emergence of *P. xylostella* by a leaf-dipping method at a concentration of LC<sub>50</sub> value. The methanol extract from all parts of *P. verticillata* and the essential oil from all parts of *I. dentata* exhibited potent activity with LC<sub>50</sub> of 6.34 and 6.53(g/L) 5days after treatment. And the essential oil from all parts of *P. verticillata* and *I. dentata* have shown strong antifeeding activity compared to those of methanol extracts against larvae of *P. xylostella*. Also, the methanol extract and essential oil of *P. verticillata* and *I. dentata* gained 37.5%, 5.0% of pupation and 22.5%, 2.5% of adult emergence, respectively.

**Key words:** *Plutella xylostella*, insecticidal activity, antifeeding activity, medicinal plant, methanol extract, essential oil

## Management of *Frankliniella occidentalis* (Thysanoptera: Thripidae) with Entomopathogenic Fungi

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Reported herein is the use of mycotized millet grains with entomopathogenic fungi applied to soil to control western flower thrips (WFT), *Frankliniella occidentalis*. The majority of mature larvae move from plants to soil for pupation. Mycotized millet grains with *Beauveria bassiana* ERL1170 and *Metarhizium anisopliae* ERL1171 were mixed in the upper layer of potting soil containing a blossomed marigold as a banker plant. *B. bassiana* GHA, a commercial isolate, served as a control. One week post application 3 mated WFT females were added per plant. At 8 wks post infestation WFT mortality in pots with ERL1170 and ERL1171 treatments was 90% and 81% respectively compared to GHA with 15% mortality. Plants in the two ERL treatments had lower levels of damage. The insecticidal activities were positively associated with the fungal soil colonization. No significant release of fungal inoculum from the potting medium was observed. These results suggest that soil applications of entomopathogenic fungi can reduce WFT populations to significantly low levels by targeting pupae. Application timing and the life cycle of WFT are important considerations.

**Key words:** Western flower thrips, mycotized millet grains, entomopathogenic fungi, pupation, soil colonization

## Compatibility of pesticides with *Beauveria bassiana* to control two-spotted spider mite *Tetranychus urticae*

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Two-spotted spider mite, *Tetranychus urticae* (Koch) is one of the serious pests in economically important crops such as strawberry and cucumber and so on. Acaricides have been used as the main control agents. This study was conducted to test the synergistic effects of the *Beauveria bassiana* GHA, which has been registered for whitefly and thrips, and five pesticides (abamectin, acrinathrin, bifenthrin imidacloprid, dinotefuran, and indoxacarb, which are commonly used pesticides in strawberry in Korea), on the two-spotted spider mite *T. urticae*. Five tested pesticides did not inhibit spore germination and mycelial growth of *B. bassiana*. Pesticides were applied to potted strawberry plants at four different treatments (recommended concentration, 1/5 recommended concentration, 1/5 recommended concentration + GHA( $10^8$  conidia/ml), and only GHA( $10^8$  conidia/ml). Mortality in larvae of two-spotted spider mite was 12% in GHA 5 day after treatment. Mortality in abamectin treated *T. urticae* was 98.5% and 100% at 1/5 recommended concentration and recommended concentration, respectively, 3 days after treatment. Acrinathrin, indoxacarbe, dinotefuran and difenthrin imidacloprid caused 60%, 14%, 16% and 91% mortality at recommended concentration 5 day after treatment. The tested five pesticides and *B. bassiana* GHA had no synergistic effect.

**Key words:** *Beauveria bassiana* GHA, *Tetranychus urticae*, Two-spotted spider mite, synergistic effect, pesticides

## 시설고추에서 천적을 이용한 해충밀도억제 효과

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시험은 2009년부터 2010년까지 전북 익산시 왕궁면 광암리 소재의 비닐하우스 고추 농가에서 2개동(660m<sup>2</sup>/동)을 임차하여 실시하였으며, 고추의 작형은 2월 하순에서 3월 상순에 정식하는 축성재배 형태이다.

단위면적(m<sup>2</sup>)당 천적 방사량은 작물생육과 해충 발생시기에 따라 진딧물 천적으로 콜레마니진딧벌(*Aphidius colemani*)을 2.3마리, 총채벌레 천적으로 미끌애꽃노린재(*Orius laevigatus*)를 3.8마리, 가루이 및 잎응애 천적으로 지중해이리응애(*Amblyseius swirskii*)를 75.8마리 방사하였다. 해충 및 천적의 밀도는 진딧물의 경우 4월 29일 잎 당 0.2마리로 최고 밀도를 보였고, 콜레마니진딧벌은 5월 14일 잎 당 0.3마리까지 증가하여 진딧물을 안전하게 억제 하였다. 총채벌레(대만총채벌레+꽃노랑총채벌레)의 경우 6월 18일 꽃 당 0.6마리로 최고 밀도를 보였고, 미끌애꽃노린재는 7월 1일 꽃 당 1.7마리까지 증가하여 총채벌레보다 오히려 천적의 밀도가 높았다. 차응애의 경우는 8월 13일 잎 당 0.4마리로 최고 밀도를 보였고, 지중해이리응애는 9월 10일 잎 당 1.6마리로 작기 동안 높은 밀도를 유지하였다. 담배가루이의 경우는 9월 10일 황색트랩 당 219.1마리로 최고 밀도를 보였고, 천적인 지중해이리응애 밀도는 차응애 천적밀도와 같다. 담배가루이 밀도가 황색트랩에 1주일동안 정착된 수가 많게 보이나, 실제 작물에서의 밀도는 매우 낮은 수준이다. 지중해이리응애는 잎응애류, 가루이류, 총채벌레류 등을 포식 광식성 천적으로 포식량은 많지 않지만 해충발생 전에 방사하여 밀도증식을 시키면 잎응애류와 가루이류의 발생 초기에 억제하는 수단으로 이용가치가 높다.

**검색어:** 고추, 천적, 지중해이리응애, 미끌애꽃노린재, 콜레마니진딧벌

## 넙제를 이용한 담배가루이 방제

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가지 담배가루이 친환경 방제기술을 개발하고자, 난황유 등 7종의 천연물질을 가지 정식 후 7일 간격으로 살포하면서 생육을 조사한 결과 관행(디노테퓨란입상 수화제 1,000배), 넙제 등이 양호하였고, 넙제, 은행잎제, 난황유에서는 약해가 발생되었다. 담배가루이 발생은 관행과 넙제 처리에서 적었다. 수량은 관행에서 가장 많았고, 친환경 자재에서는 넙제, 고추씨유 등이 많았으며, 고삼제 은행과육 등에서 적었다. 넙제 처리의 경우 관행대비 51.5%의 수량을 나타내었다.

담배가루이 방제에 효과가 우수한 넙제의 적정 처리농도를 구명하기 위하여 100~2,000배까지 5처리를 두어 가지 생육과 수량, 담배가루이 발생을 조사한 결과, 정식 48일후 생육조사에서 500배가 초장 등 생육이 양호하였고, 배수가 낮을 수록 약해가 발생과 생육이 저조하였고 배수가 증가 할수록 담배가루이 발생이 많아져 생육이 저조하였다. 담배가루이 발생은 처리 배액이 높아질수록 증가하였고, 전체적으로 넙제 500배액 처리가 과중, 과수 등이 양호하고 수량이 많아, 가지 담배가루이 방제를 위한 적정 넙제 처리농도는 500배였다.

또한 넙제 처리간격을 구명하고자, 500배 농도로 처리간격(일)을 3~15까지 5처리를 두어 담배가루이 발생과 가지 생육과 수량 등을 조사한 결과, 처리간격이 넓은 처리가 담배가루이 발생이 많았고, 생육 또한 처리간격이 넓은 10일과 15일 나빠지는 경향이였다. 또한, 넙추출물 7일 간격 처리가 과중, 과수, 상품률 등이 높아 수량이 많았다. 이는 처리간격이 짧을수록 넙제의 영향을 받았고, 길어질수록 담배가루이의 피해가 증가하였기 때문이다.

**검색어:** 약해, 처리농도, 처리간격, 상품률, 수량

## 비트 흰띠명나방 경제적방제수준

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비트에 발생하는 흰띠명나방의 경제적 방제수준을 설정하기 위하여 흰띠명나방의 생태와 접종수준에 따른 피해율 조사하였다. 흰띠명나방은 7월 중순부터 10월 하순까지 유아등에 채집되었고, 흰띠명나방은 엽맥에 3~4개씩 산란하였으며, 유충은 엽육을 갉아먹고, 엽 표피는 남기는 섭식특징을 보였다. 번데기는 5mm 정도의 황갈색이었고, 성충은 날개를 펴서 앉고, 하얀색의 선명한 띠가 있었다.

흰띠명나방 2령유충을 비트 10주당 0, 1, 2, 5, 10, 20, 50마리를 접종하고 생육을 조사한 결과 접종밀도가 증가할수록 피해엽률, 포장밀도가 증가하였다. 흰띠명나방 접종밀도가 증가할수록 비트의 수량과 상품률이 감소하였다. 비트잎을 3회에 걸쳐 수확시 접종밀도와 수량과의 관계식은 잎은  $y=1.226x+3.36$ , 뿌리  $y=0.478x+1.15$  나타내었다. 이를 근거로 잎생산 경제적 피해허용 수준은 10주당 1.3마리이고, 경제적방제수준은 1.1마리였으며, 뿌리생산 경제적 피해허용수준은 10주당 8.1마리, 경제적 방제수준은 6.4마리였다. 잎을 1회에 일시 수확 할 경우 관계식은 잎은  $y=1.537x+1.4634$ , 뿌리는  $y=0.5194x-1.1157$ 이었다. 이를 근거로 잎생산 경제적 피해허용수준은 10주당 2.3마리이고, 경제적방제수준은 1.8마리였으며, 뿌리생산 경제적 피해허용수준은 10주당 11.8마리, 경제적 방제수준은 9.4마리였다.

**검색어:** 접종수준, 유아등, 피해엽률, 잎생산, 뿌리생산

## 점착트랩이 담배가루이 밀도억제에 미치는 영향

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점착트랩을 이용한 가지 담배가루이 방제 시 최적의 설치량을 구명하기 위하여 가지 정식 후 점착트랩을 1~40개까지 6처리를 설치하고 담배가루이 성충의 유인 채집효과, 가지의 생육 및 수량을 조사하였다. 점착트랩 설치 수가 증가 할수록 초장, 경경 등 생육이 양호하였고, 잎에 발생하는 담배가루이 성충과 약충은 점착트랩수가 증가할수록 감소하였다. 트랩에 포집된 단위면적당 담배가루이 성충수는 트랩수가 적을수록 많아지는 경향이었으나 총 포집수는 트랩수가 많은 처리가 증가하였다. 생육 초기의 수량 및 과특성은 점착트랩 수가 증가할수록 과수, 상품률 등이 증가한 경향이었으나 생육후기에는 통계적인 차이가 없었다. 따라서 점착트랩에 의한 담배가루이 밀도 억제효과는 생육초기에는 있지만 생육후기에는 없었다. 생육초기 담배가루이 밀도억제에 적합한 설치수는 가지 10주당 3~5개였다

**검색어:** 설치량, 채집수, 생육, 수량

## Invention of the Portable Bark Remover (PBR) for Insect Vector Control of Pine Wilt Disease

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Pine wilt disease, caused by pine wood nematode, *Bursaphelenchus xylophilus* (Steiner et Buhner) Nickle, has become the most serious threat to pine trees in Korea since first reported in 1988. Pine wood nematode is transferred to uninfested trees by *Monochamus alternatus* (Coleoptera: Cerambycidae) (vector). A typical controlling method against vectors in Korea is fumigation of the dead trees infested by vector *M.alternatus* and *B.xylophilus* using metam-sodium SL(25%). However, this method is harmful to the environment because of the chemical contamination and vinyl waste in the mountain afterward. Portable Bark Remover (PBR) was contrived to reduce these environmental problems. The vectors oviposite under the bark of the freshly dead trees only. Debark infested trees prohibited the vectors from oviposite and finally, vectors can not complete their life cycle. The PBR is a newly designed as a debarking device that is equipped on top of the chain saw engine allowing ease and rapid debarking of the infested trees at the controlling field. Debarking of freshly-dead trees can eliminate egg-laying and hatch places where between the wood and bark from vectors. The new method for vector controlling using the debarking device is expected to lower-price and high-efficiency comparing with other conventional methods such as “crushing”, “burning” and “fumigation”.

**Key words:** Pine Wilt Disease, *Monochamus alternatus*, portable bark remover (PBR), environmental-friendly control



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## Natal host에 따른 콜레마니진디벌(*Aphidius colemani*)의 산란력과 숙주 크기 선호성의 차이

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콜레마니진디벌(*Aphidius colemani*)은 진딧물과의 생물적 방제자로서 전세계적으로 널리 이용되고 있으며, 경제적으로도 대단히 가치가 높은 분류군이다. 그러나 인위적으로 동일한 숙주에서 수 세대에 걸쳐 누대사육 될 경우 이들의 형태적 유연성은 감소하고, 숙주의 생리적 질에 따라 크기와 충질에서도 많은 차이를 나타내게 된다. 또한 숙주 선택 행동은 natal host로 부터 비롯된 표현형적 한계로 인해 제약을 받고, 공급되는 숙주의 령기 편차에 따라 기생물은 현저한 차이를 보인다.

본 연구의 목적은 대량사육 되는 콜레마니진디벌의 도태를 방지하고 생물적 방제에 적합한 품질을 지속적으로 유지시키기 위한 방법을 모색하는 것으로, natal host의 인위적 조절로 인해 발생하는 현상을 확인하는 것이다. 이에 본 연구에서는 서로 다른 두 natal host 중에서 발생한 콜레마니진디벌 개체군을 대상으로 이들의 크기 변화를 측정하고 복숭아혹진딧물(*Myzus persicae*)에 대한 각각의 산란력, 성충 크기에 따른 숙주의 크기 선호성, 그리고 두 콜레마니진디벌 개체군이 혼합되었을 때 생산량의 차이를 확인하였다.

온도 25°C, 상대습도 70%RH, 광조건 16L:8D에서 복숭아혹진딧물에 대한 콜레마니진디벌의 일일산란력(eggs/1 female/1 day)을 조사한 결과, natal host가 복숭아혹진딧물인 콜레마니진디벌은 66.4±33.9eggs, 아카시아진딧물(*Aphis craccivora*)인 콜레마니진디벌은 111.2±51.0eggs으로 전자보다 산란력이 높은 것으로 확인되었다. 기생자의 성충 크기에 따른 숙주 크기 선호성에 대해 조사한 결과, 복숭아혹진딧물에서 발생한 콜레마니진디벌 개체군의 평균 hind tibia 길이는 433.2±26.5µm로 몸길이가 0.85±0.22mm인 복숭아혹진딧물을 선호하였으며, 아카시아진딧물에서 발생한 콜레마니진디벌의 hind tibia 길이는 516.1±24.0µm로 1.21±0.26mm 크기를 선호하는 것으로 나타났다. 따라서 natal host에 따라 콜레마니진디벌의 성충 크기는 차이가 있으며, 이들의 크기와 비례하여 숙주 크기 선호성 또한 차이가 있음을 확인하였다. 이와 같은 특성을 이용하여 두 개체군이 혼합된 콜레마니진디벌을 복숭아혹진딧물에 기생시킨 결과 0.13m<sup>2</sup> 크기의 사육 cage에서 55,000 마리의 콜레마니진디벌이 생산되었으며, 이는 혼합하지 않은 두 대조군 보다 약 30% 많은 개체수로 확인되었다. 본 연구의 결과, 콜레마니진디벌의 대량 생산 체계에 있어 natal host의 인위적 변경은 콜레마니진디벌의 생리적 특성 및 충질을 변화시켜 산란력과 생산력을 증진시킬 수 있는 중요한 요소가 되는 것으로 판단된다.

**검색어:** 콜레마니진디벌, Natal host, 산란력, 숙주 선호성, 대량사육

## 조 가해 애긴노린재의 요방제 수준 설정

김현주<sup>1</sup>, 배순도<sup>1</sup>, 운영남<sup>1</sup>, 최병렬<sup>2</sup>, 남민희<sup>1</sup>, 박정규<sup>3</sup>

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조, 기장, 수수 등 잡곡은 재배면적 및 소비량이 매우 적어 2000년대 초반까지 연구자, 생산자 및 소비자로부터 크게 주목을 받지 못한 작물이었으나, 최근 국민 소득 향상 및 웰빙시대를 맞아 잡곡의 건강기능성이 크게 부각되면서 잡곡 재배면적 및 수요가 크게 증가하고 있다. 특히 최근 잡곡프로젝트 및 지역특성화사업 등 잡곡주산단지화에 따른 재배면적 및 재배지역 증가와 더불어 잡곡에 발생하는 각종 병해충도 크게 증가하고 있다. 그러나 대부분의 잡곡 주산단지들은 무농약 농산물로 인증된 지역이 많고, 또 아직까지 잡곡에 대한 병해충 발생정보가 적어 이들 병해충에 대한 재배자들의 관심 또한 매우 적다. 따라서 본 연구는 잡곡에 발생하는 해충들 중에서 조에 가장 큰 피해를 주고 있는 애긴노린재에 대한 요방제 수준을 설정하기 위하여 황금조를 공시품종으로 하여 기능성작물부내 조 포장에서 격리상(2x1.2x2m 앵글 케이지, 모기장)을 이용하여 수행하였다.

조에서 애긴노린재 약충(4-5령)의 접종밀도와 조 수량감소율과의 회귀분석식은 출수후 10일이  $Y = 0.4773X + 3.8581$ , 출수후 20일이  $Y = 0.3232X + 3.1372$ , 출수후 30일이  $Y = 0.2260X + 0.1302$  이었고, 상관계수는 각각  $R^2 = 0.9921$ ,  $R^2 = 0.9893$  및  $R^2 = 0.9964$  이었다. 따라서 조 애긴노린재 요방제 수준(5% 수량감소율)은 출수후 10일이 2.4마리, 20일은 12.9마리, 30일은 23.3마리/이삭 이었다.

**검색어:** 조, 애긴노린재, 요방제수준

## 달팽이류에 대한 인삼사포닌의 살충 및 기피효과

김현주<sup>1</sup>, 배순도<sup>1</sup>, 윤영남<sup>1</sup>, 최병렬<sup>2</sup>, 남민희<sup>1</sup>, 박정규<sup>3</sup>

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달팽이, 두줄민달팽이 및 노랑뽕족민달팽이에 대한 인삼사포닌 분말의 살충률 및 기피효과를 평가하였다. 인삼사포닌 500X와 1,000X의 노랑뽕족민달팽이 및 두줄민달팽이에 대한 분무처리 후 3일차의 살충률은 각각 100.0%와 48.1% 및 100.0%와 38.9% 이었다. 인삼사포닌 100X와 500X의 달팽이에 대한 살충률은 각각 50.0% 및 43.3% 이었다. 한편, 인삼사포닌 500X과 1,000X의 노랑뽕족민달팽이 및 두줄민달팽이에 대한 오이 절단 침지처리에 의한 처리 후 2일차의 살충률은 각각 10.0%와 0.0% 및 100.0%와 53.3% 이었다. 또한 인삼사포닌 500X와 1,000X의 달팽이에 대한 침지처리후 2일차의 살충률은 각각 53.3%와 20.0% 이었다. 한편, 인삼사포닌 500X와 구리테이프의 조합여부에 따른 노랑뽕족민달팽이의 방사 후 4일차의 누적 기피율은 인삼사포닌 500X에서 98.4%, 인삼사포닌 500X+구리테이프에서 100.0% 이었다.

따라서 달팽이류에 대한 인삼사포닌의 살충효과는 침지처리보다 분무처리에서 높았으며, 달팽이 종류에 따른 인삼사포닌의 살충효과는 껍질이 있는 달팽이보다 껍질이 없는 민달팽이류에서 높았다. 또한 인삼사포닌의 노랑뽕족민달팽이에 대한 기피효과는 98% 이상으로 매우 높게 나타나 인삼사포닌을 이용한 달팽이의 친환경 살충제 및 기피제로서의 개발 가능성을 나타내었다.

**검색어:** 달팽이류, 인삼사포닌, 살충률, 기피효과

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## 시설재배 수박에서 총채가시응애와 미끌애꽃노린재를 이용한 꽃노랑총채벌레의 밀도 억제 효과

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함안과 양구의 친환경 시설재배 수박에서 꽃노랑총채벌레의 번데기를 포식하는 총채가시응애와 총채벌레가 발생하지 않을 경우 꽃의 화분을 먹이로 생존할 수 있으며, 몸체도 다른 총채벌레 천적 보다 크기 때문에 수박과 같은 포복성 작물의 줄기 사이를 활발하게 이동할 수 있는 장점이 있어 잎, 줄기, 꽃에 서식하는 꽃노랑총채벌레의 약충과 성충을 방제하기 위하여 미끌애꽃노린재를 방사한 후 방제효과를 조사하였다. 3월(함안)과 5월(양구)에 정식한 수박 재배지에서 12~14일 간격으로 잎에 발생하는 꽃노랑총채벌레의 발생을 조사하면서 초발생이 확인되면 총채가시응애와 미끌애꽃노린재를 방사량, 방사횟수, 방사간격을 달리하여 처리한 다음 꽃노랑총채벌레의 밀도 감소 효과를 조사하였다. 그 결과 수박 정식과 함께 혹은 수박 정식 후 노란색 끈끈이트랩으로 예찰하면서 꽃노랑총채벌레가 50엽당 4~5마리가 발생하는 초기에 총채가시응애를  $m^2$ 당 15.2마리(15,000마리/300평/10a) 밀도로 토양에 방사하고, 지속적으로 잎에 발생하는 총채벌레를 예찰한 후 50엽당 약 10마리가 발생하면 미끌애꽃노린재를  $m^2$ 당 0.8마리(750마리/300평/10a) 밀도로 12~14일 사이의 간격으로 2회 방사하면 무방사구와 비교하여 90% 이상의 밀도 억제효과를 나타내었다.

**검색어:** 수박, 총채가시응애, 미끌애꽃노린재, 꽃노랑총채벌레, 밀도억제

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## Discrimination of acaricidal resistance of *Tetranychus urticae* using surface enhanced laser desorption/ionization time-of-flight mass spectrometry (SELDI-TOF MS)

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This study was conducted to examine the potential of surface enhanced laser desorption/ionization time-of-flight mass spectrometry (SELDI-TOF MS) to screen *Tetranychus urticae* resistance to pyridaben and dicofol. *T. urticae* is one of the most important pests in greenhouse and orchard, and huge expense is needed to control because of its strong resistance to acaricides. Consequently speedy and accurate monitoring of acaricidal resistance is the key factor of IPM for *T. urticae*. SELDI-TOF MS is a novel approach to biomarker discovery that combines two powerful techniques: chromatography and mass spectrometry. It can provide a rapid protein expression profile of acaricidal sensitive and resistant *T. urticae*. In this study we had different protein and peptide patterns between sensitive and resistant strains to pyridaben and dicofol. In the future this results could be a useful data to develop a good monitoring tool of site and host specific mite resistance to various acaricides.

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**Key words:** two spotted spider mite, pyridaben, dicofol, proteomics

## 참외 담배가루이 경제적 방제수준 설정

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본 연구는 참외 담배가루이에 대한 합리적 약제방제수준을 설정하기 위하여 수행하였다. 담배가루이 성충의 접종수준을 0, 0.1, 0.5, 1, 2마리/엽으로 조절하여 충태별 밀도변화 및 식물체 피해정도를 조사한 결과, 2마리/엽 처리구의 경우 담배가루이 증식속도는 접종 30일 후에 7.4마리/엽으로 3.7배 증가하였고, 접종 60일 후에는 49.8마리/엽으로 초기 접종밀도보다 24.9배 증가하였다. 담배가루이에 의한 피해는 주로 성충의 배설물에 의해서 나타나는 그을음 증상으로 2마리/엽 접종 처리구는 접종 후 20일째부터 피해가 나타나기 시작하였고, 접종 60일째에 피해과율은 31.5% 발생되었다. 담배가루이 발생밀도에 따른 피해과율과의 관계는  $y=0.961X+0.0562(R^2=0.976)$ 로 높은 상관관계가 있었다. 2007년부터 2009년까지 농산물 소득자료의 참외 평균수량과 단가, 조수입 및 방제비용을 고려하였을 때 소득지수는 95%로 나타났는데, 이 값을 기준으로 요방제수준을 계산한 결과, 경제적 피해수준의 담배가루이 밀도는 5.1마리/엽이었고, 경제적 피해수준의 80% 수준에서 경제적 방제수준은 참외 1엽에 4.1마리였다.

**검색어:** 참외, 담배가루이, 경제적 피해수준, 요방제수준

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## Repellency, Insecticidal Activity and Repellency Duration Effect of Dagalet Thyme, *Thymus quinquecostatus* var. *japonica* on Asian Tiger Mosquito, *Aedes albopictus*

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The repellency, insecticidal activity and repellency duration effect of dagalet thyme, *Thymus quinquecostatus* against Asian tiger mosquito, *Aedes albopictus* larvae and adults was investigated. Whole plant body of *T. quinquecostatus* proved to have the repellent activity of 91.2% against *A. albopictus* adults. The constituents of *T. quinquecostatus* were analyzed using GC-MS as follows:  $\alpha$ -pinene (1.1%),  $\alpha$ -thujene (2.7%), camphene (1.3%), myrcene (4.7%),  $\alpha$ -terpinene (5.0%),  $\gamma$ -terpinene (33.0%),  $\rho$ -cymene (8.3%),  $\beta$ -caryophyllene (4.0%),  $\beta$ -bisabolene (8.9%), thymol (29.9%), and carvacrol (1.2%). Among them, thymol has the perfect repellency on *A. albopictus* adults and confirmed the electrophysiological response on the antenna of *A. albopictus* adults. To enhance the maintenance, vanillin was added. Duration of effectiveness of mixture with vanillin (0.18 : 0.36  $\mu\text{l}/\text{cm}^2$ ) were significantly more prolonged than thymol alone. The constituents on its original oils were applied onto *A. albopictus* larvae. The thymol,  $\alpha$ -terpinene and carvacrol ( $\text{LC}_{50} = 9 \text{ mg litre}^{-1}$ ) revealed to have high insecticidal activity.

**Key words:** *Aedes albopictus*, electrophysiological response, repellency, thymol, vanillin

## Insecticidal Effect of Environment Friendly Agricultural Materials (EFAMs) for *Nilaparvata lugens* and *Cnaphalocrocis medinalis* on Rice

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The insecticidal effect for several commercially available environment friendly agricultural materials (EFAMs) is investigated to *Cnaphalocrocis medinalis*, *Narana aenescens*, *Pseudaletia unipuncta* and *Parnara guttata* on rice. In the insecticidal effects for 2-3rd instar larvae of lepidopteran after treatment with 19 EFAMs, more than 95% of mortality rate showed 5 EFAMs in *C. medinalis*, 12 EFAMs in *N. aenescens*, 9 EFAMs in *P. unipuncta*, and 14 EFAMs in *P. guttata*, respectively. Among 4 EFAMs selected for *C. medinalis* in indoor, more than 70% in control effect is seen EFAM-B(85.2%), EFAM-I(79.1%) and EFAM-M (78.3%), respectively, in rice field. The insecticidal effect for EFAMs is investigated to *Nilaparvata lugens*, *Laodelphax striatellus* and *Nephotettix cincticeps* on rice. In the insecticidal effects for 2-3rd nymph and adult after treatment with 19 EFAMs, more than 95% of mortality rate showed 5 EFAMs in *N. lugens* adult, 7 EFAMs in *N. lugens* nymph, 6 EFAMs in *L. striatellus*, and 5 EFAMs in *N. cincticeps*, respectively. Insecticidal effect for *N. lugens* was sustained until 10 day in rice treated with 7 EFAMs selected in indoor. Among them, EFAM-L, EFAM-P and EFAM-R was sustained in low density until 27 day. But EFAM-D, EFAM-L, EFAM-N and EFAM-S showed high density until 27 day and additional control was needed.

**Key words:** Rice, *Nilaparvata lugens*, *Cnaphalocrocis medinalis*, EFAM, Insecticidal effect



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## 노지고추에서 천적을 이용한 진딧물과 총채벌레의 생물적방제

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2010년 5월부터 8월까지 충남 태안군의 노지고추(면적 1653m<sup>2</sup>) 포장에서 진딧물류과 총채벌레류의 방제를 위해 진디벌과 으뜸애꽃노린재를 방사하고 해충과 천적의 밀도변화를 약 7일 간격으로 조사하였다. 5월 20일 황색점착트랩에 잡힌 진딧물 유시충을 확인하여 진딧물의 예방적 방제를 위해 진디벌 벙커플랜트 6포트를 포장에 옮겨 심었다. 6월 4일 조사에서 진딧물 밀도가 전 주보다 증가하여서 (진딧물 0.1마리/주) 진디벌 0.9마리/(m<sup>2</sup>)를 추가로 방사하였다. 진디벌 방사 후 6월 9일(진딧물 0.5마리/주)까지는 진딧물 밀도가 증가하였으나, 이후부터 진디벌의 머미수가 증가하면서 진딧물 밀도가 억제되기 시작하였고 7월 14일 조사에서는 진딧물 밀도가 주당 0.05마리로 낮아졌다. 6월 4일 황색점착트랩에서 총채벌레의 유입이 처음 확인되어 총채벌레류의 방제를 위해 6월 4일, 9일에 으뜸애꽃노린재 0.6마리/(m<sup>2</sup>)를 방사하였다. 이후 총채벌레의 밀도가 계속적으로 증가하는 추세여서 6월 28일에 으뜸애꽃노린재 3마리/(m<sup>2</sup>)를 추가로 방사하였다. 총채벌레 밀도는 6월 28일(꽃당 약 2마리)부터 7월 7일(꽃당 약 12마리)까지 급격히 증가되었고, 이후 애꽃노린재의 밀도가 점차적으로 높아지면서 총채벌레의 밀도가 급격히 감소하여 8월 19일에는 꽃당 2마리로 총채벌레밀도가 낮아졌다.

**검색어:** 진딧물, 총채벌레, 진디벌, 애꽃노린재, 생물적방제

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## Larvicidal Activity of Plant Essential Oil and Their Constituents against Mushroom Fly *Camptomyia corticalis*

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The larvicidal activity of 104 plant essential oils and their major constituents against third instar larvae of mushroom fly *Camptomyia corticalis* was examined using a vapor-phase mortality bioassay. Results were compared with those of the conventional insecticides dichlorvos. Over ten plant essential oils exhibited showed more than 90% mortality. At a rate of 0.2 mg/cm<sup>3</sup> air, pulegone, and thujone, exhibited 100% mortality whereas camphor, 1,8-cineole, α-pinene, thymol and menthol showed 90% mortality at 0.6 mg/cm<sup>3</sup> air. Global efforts to reduce the level of highly toxic synthetic insecticides in the agricultural environment justify further studies on the essential oils and their constituents described as potential insecticides for the control of the mushroom fly as fumigants with contact action.

**Key words:** Larvicidal activity; *Camptomyia corticalis*; essential oils, terpenoids

## 포도해충 종합방제체계

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충북지역 포도 주산단지인 청원, 옥천, 영동 지역에서 포도 주요해충별 발생밀도를 조사하여, 방제적기를 설정하였다. 발생밀도에 따른 주요 해충별 방제적기는 애무늬고리장님노린재가 5월 상순, 이슬애매미충과 이마점애매미충은 6월 중순과 8월 상순, 포도들명나방은 6월 중순과 8월 상순, 갈색여치는 6월 중순, 그리고 꽃매미는 5월 상·중순이었다. 포도 해충의 종합방제를 위하여 해충별 방제적기를 근거로 포도에 등록된 농약을 3회(5월 상·중순, 6월 중순, 8월 상순) 살포하고, 10월 말까지 해충별 밀도변화를 조사하였다. 포도해충 방제력에 의한 3회 농약 살포 후 해충밀도를 조사한 결과, 청원지역에서 발생된 해충은 애무늬고리장님노린재, 이슬애매미충, 이마점애매미충, 포도들명나방이었으나 발생밀도가 높지 않았다. 옥천지역에서 발생된 해충은 애무늬고리장님노린재, 이슬애매미충, 이마점애매미충, 포도들명나방이었고, 이슬애매미충의 밀도가 가장 높았다. 영동지역에서 발생된 해충은 공각지벌레, 포도곶추잎벌레, 애무늬고리장님노린재이었다. 포도원에 발생된 해충은, 방제적기인 5월 상·중순, 6월 중순, 8월 상순에 3회 약제방제하면, 포도에 피해를 줄 정도의 해충 발생은 없었다.

검색어: 포도, 해충, 방제체계

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## 식품원료에서의 화랑곡나방(*Plodia interpunctella*) 냉동방제

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식품회사에서 식품원료를 대상으로 실행중인 냉동방제의 효율과 경제성을 극대화하기 위하여 주요 저장해충인 화랑곡나방에 대한 땅콩 포장상태에서의 냉동처리시간 (실온, 품온이 -15℃ 도달 후 냉동시간: 24, 36, 48hr)에 따른 총태별(알, 유충)부화, 치사, 우화율 등을 조사하였다. 부화율 조사결과 대조군의 30개 소포장에서는 100% 부화하였으나 냉동처리 된 소포장에서는 0%였다. 유충 치사율은 대조군에서 23.63%의 치사율을 보였으나 실험군에서는 냉동처리시간(24, 36, 48hr)에 관계없이 100% 치사되었다 (df=3, 119, F=81876, P<0.01). 유충 우화율은 대조군에서 73.33%였고 실험군에서는 0%를 나타냈다 (df=3, 116, F=464.77, P<0.01). 냉동방제 처리 시 품온이 -15℃에 도달한 시점으로부터 24hr, 36hr, 48hr 경과한 실험군에서 화랑곡나방의 부화, 유충 우화 등이 관찰되지 않았으므로 냉동방제 시스템의 규격을 식품원료의 품온이 -15℃에 도달한 시점으로부터 24hr으로 규격화하는 것이 방제효율이나 경제성을 극대화하는 방안으로 판단되었다.

**검색어:** 화랑곡나방, 저장해충, 냉동방제, 식품해충방제

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## Insecticidal activity of microcapsulized emulsions and active compounds from plant essential oils against *Lycoriella ingenua*

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The emulsion and micro-encapsulated formulation from three essential oils, cassia, thyme white and lemon grass were tested for their insecticidal activities against *Lycoriella ingenua* (Dufour) adults at 0.3% concentration. As a result, the micro-encapsules than emulsion formulation was confirmed to show greater activity. Based on this result, insecticidal activities at several levels of concentration were examined, resulting in more than 80% insecticidal activity after 30 minutes at 0.6% level of cassia formulation. And also, insecticidal activity of three oil-based micro-encapsulated formulations lasted for up to 12 hours at 0.9% concentration. The main ingredients derived from three essential oils were evaluated on the insecticidal activity against *Lycoriella ingenua*. As a result, in case of thymol from thyme white, it showed more than 80% mortality after over 30 minutes at 0.25%, and in cinnamic aldehyde and citral, exhibited 88% and 82% mortality after 30 minutes at the 0.5% level, respectively. These three compounds were examined for whether the insecticidal activity was maintained depending on being over time. In case of thymol, it maintained good insecticidal activity against *Lycoriella ingenua* at 0.5% level until 120 hours, while cinnamic aldehyde and citral showed lower activity after 12 hours.

**Key words:** micro-encapsules, plant essential oils, *Lycoriella ingenua*, active ingredients, activity maintenance

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## Visual Preference of High Power Light Emitting Diodes (HPLEDs) to *Bemisia tabaci* (Hemiptera: Aleyrodidae)

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Sweet potato whitefly, *Bemisia tabaci*, is one of the most common and critical green house pests in the world. The object of this study was to evaluate the attraction effect of various colored high power light emitting diodes (HPLEDs) against *B. tabaci*. These insects with diverse HPLEDs were examined by LED equipped chamber in the dark room at  $27\pm 0.5^{\circ}\text{C}$  and  $60\pm 5\%$  relative humidity. Evaluated light-sources were blue ( $470\pm 10$  nm), green ( $520\pm 5$  nm), yellow ( $590\pm 5$  nm) and red ( $625\pm 10$  nm) HPLEDs, and tested with various illuminance intensity at 20, 40, 60, 80 and 100 lux. Base on the attraction rates, the green (94.4%) HPLED was the most effective against *B. tabaci*, followed by yellow (78.9%), blue (71.1%) and red (60%) HPLEDs. Furthermore, these data show that both the 80 lux intensity and 40 min light-exposure time using the green HPLED was the most suitable for attraction of *B. tabaci*. Putting all results, our data will provide the useful information for eco-friendly pest control against *B. tabaci*.

**Key words:** high power light emitting diodes, *Bemisia tabaci*, specific wavelength, illuminance intensity, light exposure time

## Phototactic Responses of Various Wavelengths and Light Conditions toward *Spodoptera exigua* (Hübner)

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The aim of this study was to evaluate light emitting diodes (LEDs) as the potential attractants against *Spodoptera exigua* on various wavelengths, light intensity and light duration, and compared to that of commercial control, fluorescent lamp. The phototactic response to *S. exigua* was tested by single and complex wavelengths. The single wavelengths were composed as follows: blue (470 nm), green (520 nm), yellow (590 nm) and red (625 nm). The complex wavelengths was combined with two single wavelengths, such as blue-green, blue-yellow, blue-red, green-yellow, green-red and yellow-red. When the optimal light condition was investigated, the all light treatments attracted the highest number of *S. exigua* at 40 lux intensity and 60 min duration. Based on the single wavelengths under optimal light condition, the green LED exhibited the highest attraction rate (88.9%), followed by blue (81.1%), yellow (63.3%) and red (56.7%), respectively. In case of complex wavelengths under same conditions, the blue-green complex (93.3%) had the significantly highest attractive activity, whereas blue-yellow, blue-red, green-yellow, green-red and yellow-red wavelengths were slightly decreased in comparison with single wavelengths. These data clearly show that blue-green complex had the greatest attraction against *S. exigua*.

**Key words:** light emitting diodes, *Spodoptera exigua*, specific wavelength, light intensity, light duration

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## 굴농응애류에 대한 친환경자재 시험 및 유기인계살충제 저항성 계통 선별

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굴농응애의 친환경자재 3종에 대한 약제감수성을 조사한 결과 허브 규, 파라포핀스, HES에 대한 약제처리 3일후의 생충율은 0%로 방제가 100%를 보였다. 굴농응애의 살비제 7종 및 친환경자재 2종에 대한 약제감수성을 약제처리 3일, 5일, 7일 후에 조사하였다. 그 결과 친환경자재인 기계유유제와 파라포핀스 HES합제가 높은 살충율을 보였으며, 살비제인 spirodiclofen, dicofol, spiromesifen, propargite, cyhexatin에 대해서도 높은 살충율을 보였다. 한편, mancozeb에 대한 굴농응애의 살충율은 8일후 45%, 10일후 56%를 나타냈다.

굴농응애의 유기인계살충제 dimethoate에 대한 저항성 계통과 감수성 계통을 선별하기 위해서 제주도 감귤원 17농가 중 dimethoate에 대하여 낮은 감수성을 나타낸 3개 농가 (S-9, J-4, S-8 계통)와 높은 감수성을 나타낸 1개 농가 (S-3 계통)에서 굴농응애를 채집하여 감수성을 검정하였다. 또한, 친환경 농가 5곳 (S-2', S-3', J-1', J-2', J-3' 계통)을 대상으로 굴농응애를 채집하여 상기의 약제에 대한 감수성을 검정하였다. 그 결과 J-4, S-8계통은 dimethoate에 대한 LC50가 905ppm, 323ppm를 나타냈다. S-3, S-2', S-3', J-1', J-2', J-3' 계통의 dimethoate에 대한 LC50는 564ppm, 140ppm, 186ppm, 97ppm, 341ppm, 206ppm으로 J-4 계통에 대한 저항성비는 각각 1.60, 6.46, 4.86, 9.32, 2.65, 4.39를 나타냈다. leaf spray 방법을 사용하여 S-9, J-4, S-8 계통을 기준사용량의 dimethoate로 처리 후 살아남은 개체를 저항성 계통으로 보고 사육하였으며 LC50가 140ppm, 97ppm으로 가장 낮은 S-2', J-1' 계통을 감수성 계통으로 보고 이를 사육하였다. 접종 3개월 후의 2차도태시 이들에 대한 LC50를 측정한 결과 J-4, S-8 계통의 LC50는 1220ppm, 635ppm으로 1차도태시 측정값과 비교하여 각각 1.34, 1.96배 증가를 보였다. 감수성 계통으로 생각된 S-2', J-1' 계통은 443ppm, 199ppm으로 이전 측정값에 비교하여 감수성이 낮아졌다. dimethoate에 대한 순수 절대 감수성 계통을 얻기 위해서는 이들 계통을 대상으로 역도태 과정이 필요하리라 생각된다. 한편, 감수성 점박이응애를 사용한 dimethoate의 LC50는 738ppm으로 J-4 계통에 대하여 1.22의 저항성비를 얻었다.

검색어: 굴농응애, 굴농응애, 약제감수성, 저항성



## Elongation and Application of Repellent Effects of Plant Essential Oils with Vanillin to *Aedes aegypti*

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Six plant essential oils, vanillin, and their mixtures were tested for repellent activities and olfactory responses in a dengue virus vector mosquito, *Aedes aegypti*. Among the plant essential oils, cassia oil showed complete protection time (CPT) of 75 minutes. CPTs of lemongrass, lemongrass, lemon eucalyptus, xanthoxylum oils, and vanillin were within 30 minutes at 5% (0.21 mg/cm<sup>2</sup>) tested level, although their CPTs were not comparable to same concentration of DEET that showed 127.5 minutes of CPT. However, their repellency effects were significantly improved in two conditions; improving concentration up to 15% level (0.63 mg/cm<sup>2</sup>) and addition of vanillin. In bioassays using binary or tertiary mixtures with one or two essential oils with or without vanillin, the composition of 1:3:1 (v/v/w) consisted of lemongrass oil, xanthoxylum oil and vanillin provided 270 min-CPT. As a practical application, the mixture of 1:1:1 formulation containing lemongrass oil, xanthoxylum oil, and vanillin (v/v/w) was enclosed into the Viscopearl, porous cellulose beads that provide gradual release of volatile compounds. Efficiently, more than 90% of repellency for 2 hours was observed in cage and semi-field chamber tests using the formulation. In addition to behavioral assays, we subsequently examined how mosquitoes sense the blends of oils with vanillin by using electroantennogram (EAG) recording. Binary mixture with one oil and vanillin, which extended CPTs, showed no significant patterns of EAG alternation, while tertiary mixtures of oils and vanillin decreased patterns of EAG responses as an increase of vanillin contents in the mixture, implying further potential roles of vanillin as a synergist in mosquito repellency. Based on behavioral and electrophysiological data, cassia, rosemary, lemongrass, xanthoxylum, and lemongrass oils could provide the high possibility for development of commercial products for useful management strategies to control mosquitoes.

**Key words:** *Aedes aegypti*, Electroantennogram, Plant essential oils, Repellency, Synergic effect, Viscopearl

## Monitoring of *Matsucoccus thunbergianae* using moving cross-shaped flat trap

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The Black pine bast scale, *Matsucoccus thunbergianae* is one of the most serious in black pine, *Pinus thunbergii* forests in Korea. Since this pest was first reported in Goheung, Korea in 1963, which is gradually spread into neighboring regions and now occurs in many regions of the southern and eastern part of the Korean peninsula. The monitoring for distribution of *M. thunbergianae* was able to observed by naked eye egg sacs and pupa of male on the host until now. Therefore, this monitoring was very difficult in the low density of *M. thubergianae*. This experiment was conducted to use simple and practical moving cross-shaped flat trap for monitoring of *M. thunbergianae*.

The monitoring of *M. thunbergianae* using the device was carried out to southern regions of the Korean peninsula. The first emergence of male showed mid. March in Namhae and late march in Busan, Jinju and Pohang. The peak of emergence showed late March in Namhae and early April in the other regions. When the number of *M. thunbergianae* intermediate nymph showed 58~59, 11~44 and 8~25 on 39.25 cm<sup>2</sup> bark area of the black pine, *Pinus thubergii* for 1 week, the number of captured its male adult was 58~83, 67~488 and 1~55 on the moving cross-shaped flat trap (10× 13cm), respectively. The low density of *M. thunbergianae* was some few the number of capture, but there were no significant difference in its high density. Also, the number of captured its male adult was no significant in the different color (yellow, red, white and blue) of the moving cross-shaped flat trap.

**Key words:** *Motsucoccus thunbergianae*, *Pinus thunbergii*, Monitoring, Moving cross-shaped flat trap

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## Insecticidal activities of methanol extracts and compounds from *Asiasarum sieboldii* against *Plutella xylostella* and *Nilaparvata lugens*

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To find an alternative for synthetic pesticides, methanol extract from plant samples were tested for their insecticidal activity against insect. The extract of *Asiasarum sieboldii* had strongly insecticidal activity against *Plutella xylostella*. Roots of *A. sieboldii* were extracted with methanol, and the concentrated extract was partitioned with *n*-hexane, ethylacetate, *n*-butanol and H<sub>2</sub>O. The highest activity was shown in the hexane fraction. Activity-guided fractionation led to the isolation of two amides from hexane fraction through the repeated silica gel column chromatographic separations. From the interpretation of spectropic data including NMR, MS, IR, the chemical structures of compounds were determined as dodeca-2E,4E,8Z,10Z-tetraenoic acid isobutylamide and dodeca-2E,4E,8Z,10E-tetraenoic acid isobutylamide. These compounds showed insecticidal activity on *P. xylostella* by 96.7% at 100ppm. The liquid formulation controlled on cabbage effectively. The extract and compounds from *A. sieboldii* showed insecticidal activity against *Nilaparvata lugens*. As a naturally occurring pesticide, *A. sieboldii* could be useful as a new botanic insecticide.

**Key words:** *Plutella xylostella*, *Asiasarum sieboldii*, insecticidal activity

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**Insecticide susceptibility of *Ephemera orientalis*  
(Ephemeroptera: Ephemeridae) and two mosquito species,  
*Anopheles sinensis* and *Culex pipiens* in the Republic of Korea**

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Field-collected populations of mayflies, *Ephemera orientalis* were tested for susceptibility to 10 different insecticides using a direct-contact mortality bioassay. *Ephemera orientalis* subimagos were susceptible to the insecticides chlorpyrifos, fenitrothion and chlorfenapyr with LD<sub>50</sub> values of 69.7, 78.8 and 81.9µg/♀, and adults had LD<sub>50</sub> values of 71.9, 78.8 and 85.4µg/♀, respectively. Susceptibility ratios(SRs) of subimagos and adults of *E. orientalis* to the 10 insecticides were 1.0 to 1.2 folds. The mayflies showed higher susceptibility to organophosphates than to pyrethroids. The SRs of *Anopheles sinensis* to *E. orientalis* were 514 to 1,438 fold higher for organophosphates (LD<sub>50</sub> values of 0.05 to 0.23µg/♀) and 62 to 1,155 fold higher for pyrethroids (LD<sub>50</sub> values of 0.13 to 2.41µg/♀). The SRs of *Culex pipiens* to *E. orientalis* were 606 to 3,595 fold higher for organophosphates with LD<sub>50</sub> values of 0.02-0.17µg/♀ and 81 to 1,365 fold higher for pyrethroids with LD<sub>50</sub> values of 0.11- 1.83µg/♀. These results indicate that the use of ineffective insecticides will result in unsatisfactory control against field populations of the subimagos and adults of *E. orientalis*.

This work was supported by a research grant from the National Vector Control and Surveillance work performed by the Korean National Institute of Health.

**Key words:** Mayfly , Mosquito, Insecticide, Susceptibility ratio, ROK

## Insecticidal activity of *Ruta chalepensis* leaf-derived component against *Sitophilus zeamais*

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Insecticidal activity of active component isolated from *Ruta chalepensis* leaves was examined against maize weevil, *Sitophilus zeamais* and compared with two different bioassay system, such as direct contact and fumigant method. The methanol extract of *R. chalepensis* leaves had strongly (++++) insecticidal activity at 50 mg/disk against *S. zeamais*. Methanol extract of *R. chalepensis* was partitioned with hexane, chloroform, ethyl acetate, butanol and water fraction, successively. In this result, the highest activity was shown in chloroform fraction against *S. zeamais*. Biologically active compound derived from chloroform fraction of *R. chalepensis* extract was purified by using SiO<sub>2</sub> column chromatography and prep-HPLC. The insecticidal constituent of *R. chalepensis* was identified as quinoline-4-carboxaldehyde by various chromatography and spectroscopic analysis methods. At 2.5 mg/disk, the most toxic activity against *S. zeamais* was exerted by the direct contact method (100%), followed by the fumigant method (23%). These results revealed that the contact toxicity showed 4.35 times greater than the respiration toxicity. Furthermore, these results indicate that quinoline-4-carboxaldehyde could be useful as a new preventive agent against damage caused by stored-product insects.

**Key words:** *Ruta chalepensis*, *Sitophilus zeamais*, direct contact method, fumigant method, stored-product insect

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**Isolation of an antifeedant compound from tree of heaven,  
*Ailanthus altissima* against diamondback moth,  
*Plutella xylostella***

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From the methanol crude extracts of the tree of heaven (*Ailanthus altissima*) leaves, the antifeedant substance was isolated and bioassayed with different concentrations against diamondback moth (*Plutella xylostella*) larvae. The antifeeding activity was evaluated by measuring the feeding area during 24 hr after inoculation. Methanol extracts showing antifeeding activity at 5000 ppm was subsequently fractionated into hexane, chloroform, ethyl acetate and water layer. Third larvae of diamondback moth was tested to each fraction layer. Chloroform layer shows the highest antifeeding activity and the layer was purified by silica gel open column chromatography. The C22 and C23 fractions showed higher antifeeding ratio with 96 and 86%, respectively, and then these two fractions were re-isolated by ODS open column chromatography. As a result, both fractions in methanol 40% (v/v) showed antifeeding ratio over 90%. The C221 fraction showed insecticidal activity in all fraction, however, C231 fraction was showed the antifeeding activity only in C2311 fraction. The C2311 fraction judging to have antifeeding activity was re-isolated and purified by HPLC and recycling, and finally obtained the bioactive substances (C23111) with antifeeding ratio with 88%. The structure of bioactive materials isolated was confirmed by LC-mass and <sup>1</sup>H-NMR(500 MHz), <sup>13</sup>C-NMR(100 MHz).

**Key words:** *Ailanthus altissima*, antifeedant, *Plutella xylostella*, chromatography

## Toxicity of C-21233 Isolated from *Juglans regia* against *Sitophilus oryzae* (Coleoptera: Curculionidae) adults

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The rice weevil, *Sitophilus oryzae*, is one of the most common storage pests worldwide of grocery shops, flour mills and warehouses. This study investigated to assess the contact and fumigant toxicities of *Juglans regia* and its active component against the *S. oryzae* adults. Using the two different bioassays against *S. oryzae* adults, the methanol extract of *J. regia* at 20 mg had the moderate (++) activity and weak (+) activity using direct contact and fumigant method, respectively. The methanol extract was partitioned with hexane, chloroform, ethyl acetate, butanol and water fraction. Ethyl acetate fraction obtained from the methanol extract showed strong (++++) and weak (+) activity at 10 mg using direct contact and fumigant method, respectively. Ethyl acetate fraction was purified by silica gel column chromatography and high performance liquid chromatography (prep-HPLC). The structure of active component was analyzed by EI-MS, <sup>1</sup>H-NMR and <sup>13</sup>C-NMR spectra, and was identified as C-21233. Purified C-21233 from ethyl acetate fraction had strong (++++) and moderate (++) activity using direct contact and fumigant method against *S. oryzae* adults. These results indicate that active component in *J. regia* derived materials could be potential candidates as a contact and fumigant for managing *S. oryzae* adults. Further studies should be performed to the structure activity relationship of C-21233 and compared with its derivatives.

**Key words:** *Sitophilus oryzae*, *Juglans regia*, direct contact method, fumigant method, high performance liquid chromatography

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## Effect of Sublethal Concentration of Flonicamid and Thiamethoxam on the Reproduction and Feeding Behavior of Green Peach Aphid, *Myzus persicae*

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This study was performed to investigate the effect of flonicamid and thiamethoxam treated at sublethal concentration (LC<sub>10</sub>, LC<sub>30</sub>) on development period, adult longevity and fecundity and the feeding behaviour of *Myzus persicae* adult. Developmental period of *M. Persicae* nymph took 5.9 days in LC<sub>10</sub>, and 6.1 days in LC<sub>30</sub> in both insecticides, comparing with control (5.7 days), it showed longer than those of the control, but there was no significance. Adult longevity treated at LC<sub>10</sub> and LC<sub>30</sub> of flonicamid was showed 13.2 and 13.7 days, respectively, and LC<sub>10</sub> of thiamethoxam was examined as 14.7 days, it showed longer than control of 11.6 days. Mean daily fecundity exhibited higher in LC<sub>10</sub> (3.1) and LC<sub>30</sub> (3.1) of flonicamid than that of control (2.5), but thiamethoxam are not. Total fecundity exhibited higher in LC<sub>10</sub> (41.8) and LC<sub>30</sub> (43.0) of flonicamid, in LC<sub>10</sub> (42.1) of thiamethoxam than that of control (29.5). Feeding behavior was examined using EPG (electrical penetration graph). EPG data indicated that flonicamid and thiamethoxam increased the duration of non-probing periods and decreased the duration of phloem ingestion.

**Key words:** *Myzus persicae*, flonicamid, thiamethoxam, sublethal concentration, electrical penetration graph



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## 배추에서 담배거세미나방(*Spodoptera litura*)의 요방제 수준 설정

최덕수, 김도익, 김선곤, 고숙주, 강범용, 김홍재

전남농업기술원 친환경연구소

가을배추에서 담배거세미나방 접종시기와 접종밀도에 따른 배추의 수량에 미치는 영향을 조사하여 요방제 수준을 설정하고자 하였다. 배추 정식 5일후 담배거세미나방 0, 5, 10, 20, 40마리/100주 접종 20일 후 피해엽율은 각각 0.9, 44.2, 60.8, 67.3, 77.7%였고, 정식 20일 후 접종은 0.7, 14.55, 19.8, 31.9, 39.9%로 정식 초기에 피해가 더 심했으며, 접종밀도가 높을수록 피해엽율이 높았다. 담배거세미나방 무접종구의 수량 1,302kg/10a를 기준으로 정식초기 40마리 접종구는 439kg으로 66.3%, 정식중기 40마리 접종구는 34.7%의 수량감소를 보였다. 유충밀도와 수량의 회귀분석 결과 정식초기는  $Y=-21.85X+1300$  ( $R^2=0.997$ ), 정식중기는  $Y=-12.1X+1382$  ( $R^2=0.998$ )로 산출되었고 이를 근거로 배추 수량 5%를 경감시키는 담배거세미나방 밀도는 정식초기는 2.9마리, 정식중기는 5.6마리였다. 배추에서 담배거세미나방 발생밀도와 수량과의 관계는 부의 상관으로 접종밀도가 높을수록 수량은 크게 감소하여 배추 수량에 담배거세미나방 발생밀도가 큰 영향을 미치는 것으로 판단되었다.

**검색어:** 배추, 담배거세미나방, 요방제수준

**Effects of Transgenic maize plants expressing *Bacillus thuringiensis* Cry1F toxin on the non-target insect *Rhopalosiphum padi* (Hom., Aphididae)**

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The impact of transgenic Bt maize plant contained Cry1F was evaluated on the oat aphid *Rhopalosiphum padi* as a non-target insect species. Slightly reduced rates of survival and alata vivipar production were observed on Bt maize than on the non-Bt maize. In addition, slightly low preference to Bt maize plant was observed. Aphid fecundity, measured as the number of offspring produced for 7 days, was higher on Bt maize than on non-Bt maize but not different significantly. ELISA test using Cry1F-antibody revealed that 26% of Cry1F protein compared to the positive control was detected from the whole body of *R. padi* when the insects were fed Bt maize for 50 days, showing that *R. padi* can carry Cry1F protein to the higher trophic level when exposed to Bt maize. Taken together, the Bt maize plant is not likely to cause any negative side impacts on non-target insect *R. padi* but Bt toxin can be transferred to higher predators via *R. padi* as it carries the toxin.

**Key words:** *Rhopalosiphum padi*, Cry1F, Bt maize, non-target insect, ELISA test

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## A Novel Serogroup of *Bacillus thuringiensis* serovar *mogi* (flagellar serotype 3a3b3d) with Mosquitocidal Activity

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*Bacillus thuringiensis* (*Bt*) strain K4 was isolated from fallen leaves which had been collected at a forest stand in Mungyeong city, Republic of Korea. The flagellated vegetative cells of *Bt* K4 were agglutinated with the H3 reference antiserum among 55 reference H-antisera. In a further test to identify subfactors, 3b and 3d monospecific antisera were reactive to the cells, followed up with introducing a novel serogroup of 3a3b3d, designated as serovar *mogi*. The strain K4 had mosquitocidal activity against Dipteran larvae, *Anopheles sinensis* and *Culex pipiens pallens*, with no Lepidopteran toxicity observed. The SDS-PAGE profile of K4 crystal protein, ovoidal-shaped, included several bands ranging from 30-75 kDa. Four putative peptides, Cry19Ba, Cry40ORF2, Cry27Aa and Cry20Aa were detected from the bands by a nano-LC-ESI-IT MS analysis. Through a thermal asymmetric interlaced PCR, *cry19Ba*, *cry40ORF2* and *cry27Aa* genes were partially cloned from K4 strain. Three *cry* genes were further found in the strain by a 454 pyrosequencing, ending up to showing 58%, 39% and 84% homology in amino acids with Cry56Aa, Cry8Ba and Cry39ORF2 toxins, respectively. This novel 3a3b3d type strain, *B. thuringiensis* subsp. *mogi*, can be used as a good resource for studying unknown mosquitocidal *cry* genes.

**Key words:** *B. thuringiensis*, novel serotype, H3a3b3d, mosquitocidal activity

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## Molecular characterization of *Autographa californica* multiple nucleopolyhedrovirus ORF43 null mutant

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ORF43 (*ac43*) of *Autographa californica* multiple nucleopolyhedrovirus (AcMNPV) is a highly conserved baculovirus gene whose function is unknown. To determine the role of *ac43* in baculovirus life cycle, we used a new AcMNPV bacmid (bAc-MK) and generated *ac43* deletion virus (*ac43KO*) by using the plasmid capture system (PCS). After transfection into *Spodoptera frugiperda* cells, *ac43KO* produced significantly different OBs which with much larger size; and especially had much single nucleocapsids compared to Ac-MK. Furthermore, *ac43KO* bacmid led to defect in transcription and expression of *polyhedrin*, which result in less OBs production. However, *ac43KO* didn't affect BV production since there's no remarkable difference of BV titer in both *ac43KO* and Ac-MK. These results demonstrate that *ac43* play an important role in polyhedrin expression, OB formation, and virion assembly.

**Key words:** AcMNPV, *ac43KO*, OBs with larger size, single nucleocapsids

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## Fibrin(ogen)olytic Activity of Bee Venom Serine Protease

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Bee venom contains a variety of protein allergens, including serine proteases. Additionally, bee venom has been used in therapeutic application through immunotherapy for bee venom hypersensitivity and venom therapy as an alternative medicine. Here we present a novel view of the application of bee venom through which bee venom serine protease exhibits fibrin(ogen)olytic activity. Compared to honeybee venom, bumblebee venom contains a larger amount of a serine protease as one of its major components. Immunologically, venom serine proteases from bumblebees did not show cross-reactivity with the honeybee venom serine protease. We provide functional evidence indicating that bumblebee (*Bombus terrestris*) venom serine protease (Bt-VSP) acts as a fibrin(ogen)olytic enzyme. Bt-VSP activates prothrombin and directly degrades fibrinogen into fibrin degradation products, defining roles for Bt-VSP as a prothrombin activator, a thrombin-like protease, and a plasmin-like protease. However, Bt-VSP did not activate plasminogen and the fibrinolytic activity of Bt-VSP is less than plasmin. These findings offer insight into the allergic reaction sequence of bee venom serine protease and its potential usefulness as a clinical agent in the field of hemostasis and thrombosis.

## Sequencing and comparison of head louse whole genome sequences with those of body louse genome

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The differences in the immune response between body lice, *Pediculus humanus humanus*, and head lice, *Pediculus humanus capitis*, were regarded as primary factors determining their differential vector competence. To find any differences in genetic components in immune system between body and head lice, whole genome sequences of head lice were determined by both SBS [sequencing by synthesis, Illumina Genome Analyzer (Illumina-GA)] and pyrosequencing (Roche GS FLX), and compared with the reference genome sequences of body lice. The short DNA reads from Illumina-GA (an average mapping depth of 50-fold) were aligned first to the body louse reference genome, to which Roche GS FLX DNA reads (an average depth of 2.5-fold) were subsequently assembled to make up gaps between mapped consensus. Total consensus showed a size of 114 Mb and a coverage of 96% of the published body louse genome sequences. From this head louse genome sequences, a total of 12,651 genes were predicted and used for comparing with the 10,775 genes previously reported from the body louse genome. The homolog analysis identified 873 head louse-specific genes and 422 body lice-specific genes. Comparison of immune response genes between both louse species showed head lice have more number of immune-related genes than body lice. Head lice were determined to possess all of the 107 immune-related genes reported in the previous study (Kim et al., 2011), suggesting that there is no difference in genetic make-up in terms of the 107 immune-related genes between body and head lice.

**Key words:** *Pediculus humanus capitis*, *P. humanus humanus*, whole genome sequencing, immune response, immune related gene, gene ontology

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**Maternal genomic imprinting alleviation by *Wolbachia* infection  
and the offspring sex in *Trichogramma kaykai*:  
A new hypothesis**

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Haplodiploid sex determination occurs in a wide range of animals, especially in Hymenoptera, where a fertilized egg develops into a diploid female and unfertilized into a haploid male. However, recent studies on diploid functional males in some wasps suggest that the simple addition of paternal gene by fertilization may not be enough to explain female offspring production in the sex determination system. Recently, activation of sex determination gene (*tra*) was found to have a pivotal role in determining the sex of *Nasonia vitripennis*. In *N. vitripennis*, *tra* is activated only on the paternal genome (i.e. sperm) not on the maternal counterpart (i.e. egg). Such parent specific activation of a gene is controlled by an epigenetic factor, DNA methylation.

However, in *Trichogramma kaykai*, *Wolbachia* induces female offspring production without sperm. Therefore all female offspring are clonal to the maternal gene. This violates the role of activated sex determination gene (*tra*) from sperm in the wasp. We hypothesize that *Wolbachia* has an ability to activate the gene by demethylation. This hypothesis indicates that the target of sex ratio distorting endosymbionts may be an upstream gene. It will enhance our understanding of evolution of haplodiploid sex determination.

**Key words:** *Wolbachia*, *Trichogramma kaykai*, parthenogenesis, DNA methylation, genomic imprinting

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## ***Bacillus thuringiensis* subsp. *aizawai* KB098과 *acrystalliferous*(*cry*-)의 비교를 통해 *cry* gene을 암호화하는 plasmid DNA 탐색**

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*cry* gene은 *Bacillus thuringiensis*(B.t.)에서 대상 곤충에 살충활성을 나타내는 내독소단백질을 형성하는 주요 유전자로 특정 plasmid DNA상에 암호화되어 있다. *B.t.* subsp. *aizawai* KB098 균주는 파밤나방(*spodoptera exigua*)에 높은 살충활성을 보이는 균주로 본 연구에서는 이 균주의 *cry* gene이 위치하는 plasmid DNA를 찾고자 하였다. 본 실험에 이용된 KB098균주는 *cryIAa*, *cryIAb*, *cryIC*, *cryID* 4개의 *cry* gene을 가지고 있으며, Plasmid DNA는 7개가 확인되었다. *Cry* gene을 암호화하는 plasmid DNA를 찾기 위해 *acrystalliferous*균주가 필요하였으며, 42°C 조건으로 48시간 열처리 후 새로운 배지에 27°C 조건으로 3일간 재배양하여 sporulation 단계에서 위상차현미경관찰을 통해 내독소단백질을 형성하지 않는 colony를 autolysis 단계까지 배양한 후에 위상차현미경으로 재확인하여 확보할 수 있었다. 획득한 14개의 *acrystalliferous*를 균주 중, 서로 다른 pattern의 plasmid DNA를 갖는 5개의 균주를 선발하였고, *acrystalliferous*재확인을 하기 위해 SDS-PAGE를 통하여 내독소단백질의 분자량인 130kDa의 band가 형성되지 않음을 확인하였으며, PCR증폭을 통해 *acrystalliferous*균주가 KB098 균주가 가지고 있는 4개의 *cry* gene을 가지고 있지 않음을 확인하였다. *cry* gene을 암호화하는 plasmid DNA를 찾기 위해 KB098균주와 선발한 5개의 균주와의 plasmid DNA pattern을 비교한 결과, 두 개의 plasmid DNA band에서의 차이가 확인되었다.

검색어: *Bacillus thuringiensis* subsp. *aizawai*, *Acrystalliferous*, Plasmid DNA



## Isolation and characterization of a highly active $\beta$ -1,4-mannanase produced by an *Eisenia fetida*-symbiotic bacterium, *Cellulosimicrobium* sp. strain HY-13

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A xylanolytic gut bacterium isolated from *Eisenia fetida*, *Cellulosimicrobium* sp. strain HY-13, produced an extracellular glycoside hydrolase capable of efficiently degrading mannose-based substrates such as locust bean gum (LBG), guar gum, mannotetraose, and mannopentaose. The purified mannan-degrading enzyme (ManS, 34,926 Da) from strain HY-13 was found to have an N-terminal amino acid sequence of DEATTDGLHVDD, which has not yet been identified. Under the optimized reaction conditions of 50°C and pH 7.0, ManK exhibited extraordinary high specific activities of 7,109 IU/mg and 5,158 IU/mg toward LBG and guar gum, respectively, while the enzyme showed no effect on sugars substituted with *p*-nitrophenol and various non-mannose carbohydrates. ManK strongly attached to Avicel, lignin,  $\beta$ -cyclodextrin, and poly(3-hydroxybutyrate) granules, but not bound to chitin, chitosan, curdlan, or insoluble oat spelt xylan. The aforementioned characteristics of ManS suggest that it is a unique endo- $\beta$ -1,4-mannanase with out additional carbohydrase activities, which differentiates it from other well-known carbohydrases.

**Key words:** *Cellulosimicrobium* sp. strain HY-13, *Eisenia fetida*, gut bacterium, Highly active endo- $\beta$ -1,4-mannanase, mannan-degrading enzyme

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## Complete Mitochondrial Genome of the Nerippe fritillary Butterfly, *Argynnis nerippe* (Lepidoptera: Nymphalidae)

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The complete mitochondrial genome sequence of the nerippe fritillary butterfly, *Argynnis nerippe*, which is listed as an endangered species in Korea, is described with an emphasis on the A+T-rich region. The 15,140-bp long circular molecule consisted of 13 protein-coding genes, two rRNA genes, 22 tRNA genes and one control region, known in insect as the A+T-rich region, as found in typical metazoans. The 329-bp long A+T-rich region located between srRNA and tRNA<sup>Met</sup> possessed the highest A/T content (95.7%) than any other region of the genome. Along with the several conserved sequences found typically in the lepidopteran insects the genome contained one tRNA<sup>Met</sup>-like and tRNA<sup>Leu</sup>(UUR)-like sequence in the A+T-rich region.

**Key words:** *Argynnis nerippe*, Mitochondrial Genome

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## Complete Nucleotide Sequence and Organization of the Mitochondrial Genome of Eri-silkworm, *Samia cynthia ricini* (Lepidoptera: Saturniidae)

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The *Samia cynthia ricini* (Lepidoptera: Saturniidae) is a commercial silk-producing insect belonging to an insect family Saturniidae in Bombycoidea. The species that has presumably been originated in India, is distributed in India, China, and Japan. Unlikely domestic silkworm the prime host plant for the species is a castor-oil plant (*Ricinus communis* in Euphorbiaceae). Recently, the eri-silkworm also is reared in Korea and is expected to be utilized for a diverse purpose. In this report, we present the complete mitochondrial genome of the species with the emphasis of a few major characteristics. The 15,384-bp long *S. cynthia ricini* (Lepidoptera: Saturniidae) mitochondrial genome was amplified into three long overlapping fragments (from COI ~ ND4, ND5 ~ lrRNA, and lrRNA ~ COI) and subsequent several short fragments using the long fragments as template. The primers for both long and short fragments were designed solely for lepidopteran genomes, without any species-specific primers. As a usual the genome is composed of 37 genes: 13 protein-coding genes (PCGs), two rRNA genes, and 22 tRNA genes, and one large non-coding region termed the A+T-rich region. Arrangement of the genome is identical to those of other lepidopteran mitochondrial genome, but this differs from the common arrangement found in a diverse insect order, by the movement of tRNA<sup>Met</sup> to a position 5'-up stream of tRNA<sup>Ile</sup>. Unlikely previous report on the start codon for COI gene in Lepidoptera *S. cynthia ricini* COI gene starts with typical ATT codon located between tRNA<sup>Tyr</sup> and the beginning region of COI gene. The 22 tRNAs that are interspersed throughout the mitogenome ranged in length from 62 to 71 bp. All tRNAs but tRNA<sup>Ser</sup>(AGN) were shown to be folded into the expected cloverleaf secondary structures. More detailed structural and phylogenetic analyses among Bombycidae and Saturniidae in connection with other families in the Bombycoidea will be performed soon.

**Key words:** *Samia cynthia ricini*, Saturniidae, Lepidoptera, Mitochondrial Genome

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## Comparison of immune responses between body and head lice following bacterial challenge

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Body and head lice (*Pediculus humanus humanus* and *Pediculus humanus capitis*, respectively) are typical ectoparasites of humans. They differ not only in the ecological habitat but also in the vector competence in spite of their conspecific nature. Only body lice transmit several bacterial pathogens to humans, including *Bartonella quintana*, *Rickettsia prowazekii* and *Borrelia recurrentis*. In this study, the proliferation rates of two model bacteria, a gram positive *Staphylococcus aureus* and a gram negative *Escherichia coli*, were determined following bacterial challenge by cuticular injection. Both bacteria proliferated rapidly in body lice at the early stage of bacterial challenge but not in head lice, suggesting that head lice have more sensitive immune responses to these bacteria. *In vivo* phagocytosis assay revealed that head lice have much higher phagocytic activity against *E. coli* than body lice whereas only slight differences in phagocytic activity against *S. aureus* were observed between the two lice species. Taken together, these findings suggest that the reduced phagocytosis activity of body lice contributes, at least in part, to their higher vector competence.

**Key words:** *Pediculus humanus humanus*, *Pediculus humanus capitis*, Human lice, Bacterial challenge, Immune response, Phagocytosis, Vector competence

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## Molecular Cloning, Expression and Genomic Structure of Glyceraldehyde-3-Phosphate Dehydrogenase from the Entomopathogenic fungus, *Paecilomyces tenuipes* Jocheon-1

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Presently, We have constructed an olig-d(T) primed directional cDNA library from the silkworm Dongchunghacho, an entomopathogenic fungus, of which species is belonging to *Paecilomyces tenuipes* Jocheon-1. To isolate and screen genes in the fungus, 626 expressed sequence tags(ESTs) were generated by a partial sequencing from the cDNA library. *Paecilomyces tenuipes* Jocheon-1 cDNA encoding the glyceraldehyde-3-phosphate dehydrogenase(Pt-GAPDH) of *Paecilomyces tenuipes* Jocheon-1 was cloned from the above cDNA library.

The complete cDNA sequence of *Pt-GAPDH* is comprised of 1,014bp encoding 338 amino acid residues. The deduced protein sequence of Pt-GAPDH showed higher homology with *Beauberia bassiana*-GAPDH(93% amino acid identity). Hydrophathy analysis revealed that Pt-GAPDH protein is hydrophilic. The major three amino acids in its composition of amino acid residues were alanine(11.54%), valine(9.47%) and glycine(8.88%). The cDNA encoding Pt-GAPDH was expressed as a 37 kDa polypeptide in baculovirus-infected insect Sf9 cells.

The *Pt-GAPDH* gene of *Paecilomyces tenuipes* entomopathogenic fungus consisted of three exons and two introns coding for 338 amino acid residues, and the genomic DNA length of the gene spans 1302bp. The accession number of the gene in GenBank are GU997099 for *Pt-GAPDH* cDNA and GU997102 for *Pt-GAPDH* genomic DNA.

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## Molecular Cloning, Expression and Characterizaion of Heat Shock Protein Gene from *Paecilomyces tenuipes* Jocheon-1

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In this study, a full-length heat shock protein88 complementary DNA (cDNA) of *Paecilomyces tenuipes* Jocheon-1 was obtained by screening of *P. tenuipes* Jocheon-1 Uni-Zap cDNA library and 5' RACE polymerase chain reaction. The *Paecilomyces tenuipes* Jocheon-1 heat shock protein88 cDNA contains an open reading frame of 2,139 bp encoding 713 amino acid residues. The deduced amino acid sequence of the *P. tenuipes* Jocheon-1 HSP88 cDNA showed 77% identity to *N. haematococca* HSP88 and 45-76% identity to other fungi HSP88. Phylogenetic analysis and BLAST program analysis confirmed that the deduced amino acid sequences of the *P. tenuipes* Jocheon-1 HSP88 gene belonged to the ascomycetes group within the fungal clade and *P. tenuipes* Jocheon-1 HSP88 also contains the conserved ATPase domain at the N-terminal. The cDNA encoding *P. tenuipes* Jocheon-1 HSP88 was expressed as a 88 kDa polypeptide in baculovirus-infected insect Sf9 cells.

Under different stress conditions, mRNA expression of *P. tenuipes* Jocheon-1 HSP88 were quantified by real-time PCR and the result showed that heat shock stress affected the mRNA expression levels of *P. tenuipes* Jocheon-1 HSP88.

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**Genomic Structure of the Heat Shock Protein88 genes of  
*Paecilomyces tenuipes* Jocheon-1, *Paecilomyces tenuipes*,  
*Cordyceps militaris* & *Cordycepspruinosa***

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The genomic structure and phylogenetic relationships of HSP88 genes from *P. tenuipes* Jocheon-1, *P. tenuipes*, *C. militaris* and *C. pruinosa* are described. The HSP88 genomic DNA from *P. tenuipes* Jocheon-1, *P. tenuipes* and *C. militaris* all contain 5 introns and 6 exons with the length of 13, 62, 32, 1438, 306, 288 bp, encoding 713 amino acid residues. *C. pruinosa* HSP88 genomic DNA contains 4 introns and 5 exons encoding 713 amino acids. The length of each exon of *C. pruinosa* HSP88 is 13, 62, 32, 1744, 288 bp and the length of exon 4 is identical to the total length of exon 4 and exon 5 of HSP88 of *P. tenuipes* Jocheon-1, *P. tenuipes*, and *C. militaris*. The deduced amino acid sequence of *P. tenuipes* Jocheon-1 HSP88 showed 99% identity with the *P. tenuipes*, 97% identity with the *Cordyceps militaris*, and 98% identity with the *C. pruinosa*. Phylogenetic analysis confirmed that the *P. tenuipes* Jocheon-1, *P. tenuipes*, *C. militaris* and *C. pruinosa* HSP88 are placed together within the ascomycetes group of fungal clade.

## 부산우단풍뎡이에 의한 복숭아 꽃 피해증상

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본 연구는 경북 의성군 봉양면 소재 복숭아 재배농가에서 개화전인 꽃눈에 이상 증상이 발생하여 피해원인을 구명하기 위하여 실시하였다. 2010년 4. 20일 기온이 급상승하면서 피해가 발생하였는데 6,000㎡의 복숭아 과원에 70% 이상 발생하였고 주변의 과원에서도 피해가 확인되었다. 피해증상은 개화전인 꽃눈의 중앙 및 상단부가 칼로 절단한 것처럼 보이고 꽃눈을 확대해 보면 수술과 암술대가 일정하게 잘려져 있다. 일부 꽃눈은 꽃잎을 둘러싸고 있는 인편과 꽃잎이 같이 잘려져 있는 현상도 관찰되었다. 가해해충은 부산우단풍뎡이(*Maladera fusania* Murayama)로 몸 길이는 10mm 내외의 난형으로 적갈색 또는 흑색이었다.

**검색어:** 복숭아, 꽃눈 피해, 부산우단풍뎡이



## Antimicrobial Activity of Bacteriocins from *Bacillus thuringiensis* subsp. *cameroun*

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*Bacillus thuringiensis* (*Bt*) is characterized by its ability to synthesize crystal toxins and also able to produce bacteriocins such as thuricin, tochicin, entomocin and bacthuricin. The present work, for the first time, describes the biological activity of bacteriocins from *B. thuringiensis* subsp. *cameroun* (*Btc*). Supernatant which was produced from a liquid culture of *Btc* had antimicrobial activity against *Bacillus cereus*, ending up to making a inhibition zone on an agar medium. A significant reduction in antimicrobial activity was observed when the supernatant was exposed to heat at 75~100°C for 15 min. Proteins were separated from the supernatant by a fast protein liquid chromatography (FPLC) given the thermal instability. A group of FPLC fractions had antimicrobial activity against *Bt* subsp. *palmanyolensis*, *israelensis*, 1-3, *morrisoni*, *toguchini* and *kurstaki*, and *B. cereus* ACTC21768, ATCC14579 and NRRLB-569. Interestingly, when the supernatant was individually incorporated into the liquid cultures of *Bt* subsp. *israelensis* (*Bti*) and *mogi* (*Btm*) with mosquitocidal activity, a vegetative cell growth was observed only in the *Btm* culture 10 h post-incubation. A possible recovery of vegetative *Btm* cell growth was observed, compared to a control without the supernatant. These results suggest that *Btc* produced proteinous antimicrobial substances, one of which may be used as a selection marker to separate *Btm* after possibly conjugating the two mosquitocidal strains.

**Key words:** Bacteriocin, *Bacillus thuringiensis*, Antimicrobial activity, Selection marker

## Differential Gene Expression Profiles in the Salivary Gland of *Ranatra chinensis* (Hemiptera: Nepidae)

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To determine differential gene expression profiles in the salivary gland of a water stick-insect, *Ranatra chinensis* Mayrt, a subtractive cDNA library was constructed by suppression subtractive hybridization. The salivary gland was determined among three salivary gland-like tissues by investigating transcription levels of five trypsin genes isolated from *R. chinensis*. The major transcripts encoding trypsins (64.4% of the total ESTs) were eliminated from the library and then remaining salivary gland-specific genes were searched. A total of 643 expressed sequence tags (ESTs) were clustered and assembled into 148 contigs (49 multiple sequences and 99 singletons), among which 35 contigs had matched BLASTx hits ( $E \leq 1.00E-4$ ). Salivary apyrase occupied 5.6% (36 ESTs) of the library. Apyrase is known to be released by female mosquitoes or blood-sucking assassin bugs to prevent blood clots during blood sucking. Therefore, apyrase in the salivary of *R. chinensis* might allow *R. chinensis* to facilitate feeding. Several contigs encoding acid phosphatase, hyaluronidase, prophenoloxidase, and dipeptidylpeptidase IV, commonly found in venoms of Hymenoptera, were also identified from the salivary gland-specific library. Discovery of salivary gland-specific genes should promote further studies on biologically active components in the saliva of *R. chinensis*.

**Key words:** *Ranatra chinensis*, salivary gland, EST library, apyrase

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## Production and Immunogenicity of Classical Swine Fever Virus Envelope Glycoprotein E2 as Recombinant Polyhedra in Baculovirus-Infected Silkworm Larvae

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The silkworm-baculovirus expression system has distinct advantages, such as a high yield and safe usage in vertebrates. Here, we report a novel strategy for the large-scale production of a classical swine fever virus (CSFV) envelope glycoprotein E2 in the larvae of a baculovirus-infected silkworm, *Bombyx mori*. We constructed a recombinant *B. mori* nucleopolyhedrovirus (BmNPV) that expressed recombinant polyhedra together with the N-terminal 179 amino acids of CSFV E2 (E2 $\Delta$ C). BmNPV-E2 $\Delta$ C-infected silkworm larvae expressed native polyhedrin and approximately 44-kDa fusion protein that was detected using both anti-polyhedrin and anti-CSFV E2 antibodies. Electron and confocal microscopy both demonstrated that the recombinant polyhedra contained both the fusion protein and native polyhedrin were morphologically normal and contained CSFV E2 $\Delta$ C. The CSFV E2 $\Delta$ C antigen produced in BmNPV-E2 $\Delta$ C-infected silkworm larvae reached 0.68 mg per ml of hemolymph and 0.53 mg per larva at 6 days post-infection. Six-week-old female BALB/c mice that were immunized with the E2 $\Delta$ C protein purified from solubilized recombinant polyhedra elicited CSFV E2 antibodies, which indicated that the CSFV E2 $\Delta$ C protein from recombinant polyhedra was immunogenic. The virus neutralization test showed that the serum from mice that were treated with E2 $\Delta$ C protein from recombinant polyhedra contained significant levels of virus neutralization activity. These results demonstrate that the present strategy can be used for the large-scale production of CSFV E2 antigen.

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## The venom composition of the Cambodia wasp *Vespa tropica* resolved by the analyses of venom gland-specific EST and proteome

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*Vespa tropica* is a tropical species of *Vespa* found in Southeast Asia. *V. tropica* wasps were collected from rural provinces of Cambodia, and their total RNA and venom were extracted on site. To search for novel substances in venom, a subtracted cDNA library specific to the venom gland and sac was constructed and venom protein was analyzed by nano-LC-MS/MS. A total of 1127 expressed sequenced sequence tags (ESTs) were sequenced and assembled into 572 contigs (152 multiple sequences and 420 singletons). The short venom peptides were identified to be encoded from 5 contigs (43 ESTs) by proteomic analysis. In addition, putative antimicrobial peptides together with typical major components of wasp venom (venom allergen 5, mastoparan-like peptide, serine protease, and hyaluronidase) were identified in the EST Library. Additional in-depth annotation would be required for further characterization of many unidentified genes found in the EST library.

**Key words:** *Vespa tropica*, Venom, EST Library, Suppression subtractive hybridization

## Investigation for Expression of the Porcine Pseudorabies Virus Glycoproteins in Bacteria and Insect Cells

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Aujeszky's disease (AD), also called pseudorabies, is an infectious viral disease caused by an alpha herpes virus and has domestic and wild pigs, as well as a wide range of domestic and wild animals, as the natural host. Aujeszky's disease virus (ADV) virions contain several envelope glycoproteins. Among them, glycoproteins gB, gC and gD are regarded as the major immunogenicity proteins and the antibodies induced by them can neutralize virus in vitro or in vivo. In this study, we investigated expression of these glycoproteins using the bacterial and baculovirus expression system. Successful expression of ADV glycoproteins in *E. coli* was confirmed by SDS-PAGE and Western blot analysis and their optimal expression condition was determined. However, the recombinant proteins generated in the bacterial expression system which lacks glycosylation process frequently lose their biological activity. We tried to express the ADV glycoproteins using the baculovirus expression vector system. The recombinant gB, gC and gD were detected at approximately 100, 60 and 50 kDa on SDS-PAGE and Western blotting, respectively. The optimal expression conditions were determined for MOI(multiplicity of infection) and post-infection days. One MOI and 4 or 5 days post-infection were the best conditions for the expression of the ADV glycoproteins in Sf21 cells. We are currently investigating the antigenicity of recombinant proteins using experimental animals.

**Key words:** Aujeszky's disease virus, glycoproteins gB, gC and gD, Bacterial and Baculovirus expression system

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## 약리반응속도론 모델을 적용한 항바이러스성 생화학 작물보호제의 약효검정 및 작용기전 탐색 기술

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약리반응속도론(Pharmacokinetics) 모델을 적용하여 최근 개발되고 있는 항바이러스성 생화학 작물보호제의 정량적 약효 검정 및 작용기전 탐색 기술을 개발하고자 본 연구에서는 이를 위한 약리반응속도론적 파라미터를 아래와 같이 정의하고 사례 실험을 수행하였다. 시험약제를 식물체 또는 바이러스 매개충에 분무처리하고 (매개충의 보독화 직후 약제처리 하고 시험 유묘에 충 접종) 경과 시간에 따라 시험 유묘에서 바이러스의 발병율을 검정하면 약효에 따른 발병율을 무처리와 비교 가능하다. 이 때 시간에 따른 발병율의 회귀 곡선식에서  $MVIT_{50}$  (바이러스 전달 후 감염율 50%에 도달하는 시간),  $MAT$  (Mean Antiviral Time =  $|MVIT_{treated} - MVIT_{control}|$ ),  $AUG$  (Area Under Graph), 약효의 정량적 값인  $F$  value ( $=AUG_{treated}/AUG_{control}$ )를 얻을 수 있다. 애멸구에 의해 영속전염하는 벼줄무늬잎마름병바이러스(Rice Stripe Virus, RSV)에 대하여 신규 개발된 2종의 항바이러스성 생화학 작물보호제로 상기와 같이 약효 검정 시험을 수행한 결과,  $f(x)=a(1-\exp(-bx))^c$ 의 회귀곡선식이 얻어졌으며 무처리구에서  $MVIT_{50}$ 이 1시간,  $MAT$ 는 0,  $F$  value가 1.00으로 계산되었다. 이에 비해 시험 약제인 KNF2016은  $MVIT_{50}$  5.75,  $MAT$  4.75,  $F$  value 0.71, KNF2022는  $MVIT_{50}$  5.55,  $MAT$  4.55,  $F$  value 0.70으로 확인되었다. 즉, 본 시험 약제는 무처리와 비교하여 각각  $F$  value로 0.29, 0.30의 항바이러스 약효가 있었다. 1회 처리에 따른 약효 지속기간도 KNF2016이 13.4일, KNF2022가 14일 이상으로 검정되었다. 애멸구 보독충에는 약제처리를 안하고 시험 유묘에만 경엽처리 후 보독충을 접종할 때, 보독충에서 바이러스는 검정되면서 항바이러스 효과는 시간에 따라 감소하는 것으로 확인됨에 따라 본 시험 약제들을 처리한 벼를 애멸구가 흡즙하더라도 보독충 체내 바이러스에는 영향을 끼치지 않는 것으로 추정되었다. 따라서 약리반응속도론 모델을 사용하면 항바이러스 작물보호제의 정량적 약효 평가가 가능함과 동시에 약제의 작용기전 탐색에도 유용한 기술로 평가되었다.

**검색어:** 약리반응속도론, 항바이러스 작물보호제, 약효 평가, 매개충

## Enhanced Expression of the ORF2 Protein of Porcine Circovirus Type2 using Baculovirus

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Porcine Circovirus Type2 (PCV2), a single-stranded DNA virus associated with Postweaning multisystemic wasting syndrome (PMWS) of swine, has two major open reading frames, ORF1 and ORF2. The genomic size and molecular weight of ORF2 is respectively 699bp, 28kDa. ORF2 encodes the capsid protein (structural protein) that has type-specific epitopes and is very immunogenic and associated with the induction of neutralizing antibodies, suggesting its potential use in diagnostic assays as well as vaccine development. For efficient production of the capsid proteins, we expressed the PCV2 ORF2 gene with baculovirus in the insect cells. In this study, PCV2 ORF2 was appropriately ligated into the baculovirus transfer vector, pBacPAK9 and pB9-Acpol19-110-EK. Sf21 cells were transfected with a mixture of the purified recombinant transfer vector and bAcGOZA. We generated and purified recombinant viruses containing PCV2 ORF2, and named rAc-B9-PCV2ORF2 and rAc-B9-19-110-EK-PCV2ORF2, respectively. Expression levels of capsid fusion proteins with a partial polyhedrin region of AcNPV more increased than recombinant proteins from non-fusion expressed. Also, expression efficiency increased over time and differed at MOI. As a results, fusion expression of porcine circovirus type2 ORF2 using baculovirus could be utilized as an alternative expression method to produce recombinant antigen against PCV2 infection and is worthy of further investigation.

**Key words:** Porcine circovirus, PMWS, Baculovirus, AcNPV, Fusion expression

## Efficient Production of Recombinant Protein in HSPs (Heat Shock Proteins) Transgenic Silkworm

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Many thousands of recombinant proteins have been successfully produced in baculovirus - infected insect cells and larvae. In this study, to improve its value and the yield of recombinant protein production, we constructed transgenic silkworm using Heat shock genes with regard to protein folding. This time, we adapted *GAL4/UAS* system to express at necessary time point and to carry genes for foreign protein. First, we generated two transgenic cells and silkworm lines that carried the silkworm heat shock proteins, *UAS-HOP* and *UAS-HSC70* and *UAS-HSP70* and *UAS-HSP40* construct plus *3xP3-DsRED*. Subsequently, to drive the *GAL4* gene as activatorvector, we engineered Baculoviruses that contain the *GAL4* under the P10 promoter linked to the expression cassette of interest foreign genes under the polyhedron promoter. Also, activator vector linked to the *GAL4* was designed expressing 6xHis and 6xHis-GST tag. Infection of silkworm larvae with recombinant virus, His-tagged human C3d gene was more efficiently produced transgenic silkworm than that of wild-type, but not His-GST tagged. We show the possibility in use of HSPs transgenic silkworm system by *GAL4/UAS BmNPV* that can generate the efficient production of foreign protein.

**Key words:** Silkworm, Baculovirus, Heat shock protein, Recombinant protein, UAS/Gal4