Journal für Kulturpflanzen, 69 (1). S. 16–24, 2017, ISSN 1867-0911, DOI: 10.1399/JfK.2017.01.03 Verlag Eugen Ulmer KG, Stuttgart

Mitteilung

Heidrun Vogt[1], Annette Herz[2], Kirsten Köppler[3], Monica Frosch[4], Günter Hoos[5], Sandra Müller[6], Marco Roelcke[7], Conrad Graf von Hoyos[7]

Report about the German-Chinese Workshop on Prevention and Control of Spotted Wing Drosophila, *Drosophila suzukii*, held in China, June 16–20, 2015

Bericht über den Deutsch-Chinesischen Workshop zur Vorbeugung des Befalls und zur Bekämpfung der Kirschessigfliege, *Drosophila suzukii*, in China, 16.-20. Juni 2015

Background and previous history of *Drosophila suzukii* as new pest in Europe and Germany

The Spotted Wing Drosophila (*Drosophila suzukii*, Matsumura, 1931), also known as cherry vinegar fly, originates in Asia and was first described in Japan (Kanzawa, 1939). It belongs to the vinegar flies (Diptera: Fam. Drosophilidae). Typical trait of the male insects is a dark spot at the tip of the wings (Fig. 1). In contrast to other species of the same genus it attacks healthy fruit, possesses a very wide array of host plants and an enormous reproductive capacity. In Europe the Spotted Wing Drosophila (SWD) was first observed in 2008 in Spain and Italy (Cini et al., 2012, Vogt et al., 2012a); in Germany it was detected for the first time in late summer 2011 in Bavaria, Rhineland-Palatinate and Baden-Württemberg (Vogt et al., 2012b). In the first years of its occurrence in Germany, fruit infestations were observed predominantly in the southern and southwestern regions, mainly in blackberries, elderberry, blueberries and late raspberries. In 2014, following a relatively mild winter and frequent rainfall throughout the year, most severe damages were reported all over Germany on a wide range of fruit crops, including cherries and in some grape varieties as well. Furthermore, many non-cultivated host plants were infested (Vogt, 2014; Köppler and Vogt, 2015) contributing to the population growth. In cultivated fruits, fruit losses of several million € were reported. Comparable infestation levels and economic losses in fruit crops occurred in 2016, after a mild winter and favourable weather conditions with moderate temperatures and high humidity in spring and summer.

In the meantime the species is ubiquitously distributed in Western and Central Europe (Asplen et al., 2015). It has already caused great damage and has an enormous economic impact. Spotted Wing Drosophila now constitutes an existential threat for many cultivated fruit species, and to a limited extent to grapes due to lower and variety dependent susceptibility (Ioriatti et al., 2015; Hoffmann, 2015).

Need for extension services of German fruit growing and winemaking industries

On the part of the fruit and wine growers but also politics, the fast spread across the country and the dimension of damage led to strong apprehensions of crop losses in

Institute
Julius Kühn-Institut (JKI), Institut für Pflanzenschutz in Obst- und Weinbau, Dossenheim, Germany[1]
Julius Kühn-Institut (JKI), Institut für Biologischen Pflanzenschutz, Darmstadt, Germany[2]
Landwirtschaftliches Technologiezentrum Augustenberg (LTZ), Karlsruhe, Germany[3]
Regierungspräsidium Gießen, Dez. 51.4 Pflanzenschutzdienst, Wetzlar, Germany[4]
Dienstleistungszentrum Ländlicher Raum (DLR) Rheinpfalz, Neustadt/Wstr., Germany[5]
Landwirtschaftskammer Nordrhein-Westfalen, Fachbereich 62 – Pflanzenschutzdienst, Obstbau, Münster, Germany[6]
German-Chinese Agricultural Center (DCZ), Zhong Ou Hotel, Chaoyang District, Beijing, PR China[7]

Correspondence
Dr. Heidrun Vogt, Julius Kühn-Institut (JKI), Institut für Pflanzenschutz in Obst- und Weinbau, Schwabenheimer Str. 101, 69221 Dossenheim, Germany, E-Mail: heidrun.vogt@julius-kuehn.de

Accepted
15 November 2016

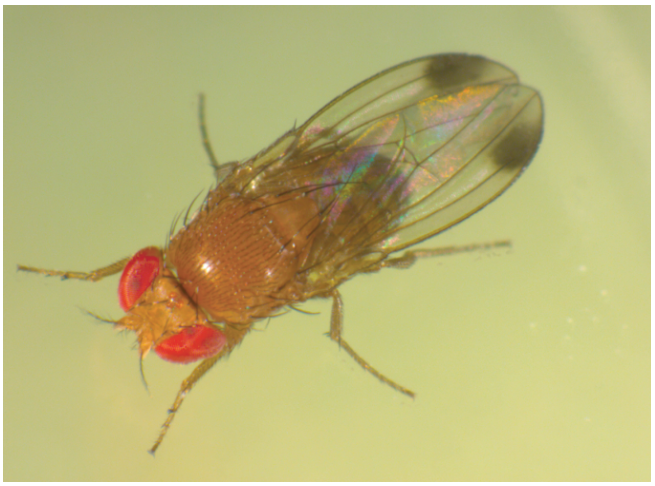

Fig. 1. Male *D. suzukii* with the typical dark spot at the tip of the wings (photo J. Just, JKI Dossenheim).

the future. An effective and sustainable pest management is still lacking due to the short time since arrival of SWD and basic research on biology, population dynamics and host range is required (Asplen et al., 2015). There is a very great need for consulting and advice on the part of the German fruit growing and winemaking industries. On a national basis in Germany, since several years the „SWD working group" („Arbeitsgruppe Kirschessigfliege") is serving as a platform for information and knowledge exchange and for the coordination of the need for action as well as of treatment strategies, in close coordination between German Federal institutions, research and State Ministries (Köppler and Vogt, 2013; Vogt and Köppler, 2014; Köppler and Vogt, 2015). The plant protection services of the German States are providing a timely and region-specific consulting service for the farmers concerned including information on infestation occurrence and on control measures in the various crops. In the Division Plant Protection of the German Federal Ministry of Food and Agriculture (BMEL) regular expert talks on the „National Control Strategy on SWD" are held.

One approach in basic as well as applied research is to find out more about how to deal with a crop pest in its region of origin. A delegation of experts from the Julius Kühn-Institut (JKI, Federal Research Centre for Cultivated Plants) travelled to Japan in April 2015, in order to gain experience in possible prevention and control measures against the pest in its home region (East Asia), of natural antagonists such as parasitoids, etc. The same objective was envisaged with a visit to China, were *D. suzukii* is likewise a pest on a range of fruit crops, especially in bayberry *(Myrica rubra,* Siebold and Zucc.) plantations. Since the last decade, aspects of biology and ecology of *D. suzukii* have been intensively studied and pest management systems have been developed by Chinese research institutions.

Preparation and Institutional involvement

During the visit to Germany by the Chinese Minister of Agriculture, Mr. Han, Changfu as part of the third Sino-German government consultations in October 2014, the German Minister of Agriculture Dr. Christian Schmidt mentioned the strong interest on the German side in a scientific exchange on the topic of SWD. This was based on an original idea by the Division Plant Protection of BMEL. Since the Chinese side possesses long-term experience, the German side expressed its wish on an exchange with the Chinese Ministry of Agriculture (MOA) in the field of control of SWD. In order to initiate such an exchange, the Chinese side therefore suggested to carry out an expert meeting on prevention and control of SWD.

With the opening of the German-Chinese Agricultural Center (DCZ) by the German Minister of Agriculture Schmidt and his Chinese colleague Minister Han on March 23, 2015, an important framework was created in order to further deepen bilateral research and cooperation in agriculture and forestry. The expert meeting on an improved control of the fruit crop pest SWD planned for the summer of 2015 was also explicitly mentioned. In early April 2015, the German and Chinese Permanent Directors of DCZ decided to hold this German-Chinese Workshop, both as first major activity of the DCZ, as well as its first concrete activity in the field of agricultural research cooperation.

The Department of International Cooperation of MOA was the leading institution and the National Agro-Technical Extension and Service Center (NATESC) of MOA was the executing agency of the workshop. Operationally, it was organized by the two implementing agencies of the DCZ, the German Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and the Foreign Economic Cooperation Center (FECC) of MOA.

The objective of the „German-Chinese Workshop on prevention and control of Spotted wing vinegar fly„ was not only to exchange state of the art in research and pest management in both countries, but also to determine research proposals for potential cooperation in the future. Following the workshop, a scientific excursion to the *Myrica* production area in Yunnan Province as well as a visit of Yunnan Agricultural University (YAU) in Kunming took place.

Workshop

The scientific workshop was held at the DCZ in Beijing on June 16 and 17, 2015. On part of the German BMEL besides scientists from the JKI, experts from the plant protection services of the German Federal States had been contacted. A total of six experts were invited as speakers on the German side. The German delegation was led by Mrs. Dr. Heidrun Vogt, Institute for Plant Protection in Fruit Crops and Viticulture, Julius Kühn-Institut (JKI) Federal Research Centre for Cultivated Plants, Dossenheim, Germany. On the Chinese side led by Dr.

Yang Puyun, Director of the Division of Pest Control, National Agro-Technical Extension and Service Centre (NATESC) of MOA, eight experts from the NATESC, the Chinese Academy of Agricultural Sciences (CAAS), as well as from several Chinese agricultural universities and agricultural research academies took part as speakers.

Scientific sessions – June 16, 2015

The workshop was opened by Dr. Chen Youquan, Deputy Director-General, Department of Crop Production of the Ministry of Agriculture and Ms. Martine Püster, Counsellor for Food and Agriculture, German Embassy. The workshop included 14 contributions from Chinese and German scientists. These considered biology and pest status of *D. suzukii* (Drosophilidae) in both countries and tephritid fruit flies *Bactrocera* sp. (Tephritidae) in China and summarized current research efforts and strategies for pest management and measures to prevent accidental introduction through surveillance and quarantine.

True fruit flies of the genus *Bactrocera* sp. are major pests in fruit crops (citrus, mango and others) in China. In recent years an area-wide Integrated Pest Management (IPM) programme was introduced in more than 600 plantations with about 200 ha which is mainly based on careful monitoring, application of bait sprays (protein bait) and implementation of strict orchard sanitation. Most important was the dissemination of this IPM programme to farmers via training, field schools and demonstration plots, as stressed by Dr. Yang Puyun, of NATESC. To improve control methods for *B. minax* towards more eco-friendly strategies (especially more effective trapping), current research on behavioral and physiological aspects (feeding, mating, oviposition and diapause) of this fly was reported by Prof. Niu Changying, Huazhong Agricultural University. Feasible methodology for sterile insect technique (SIT) as area-wide management strategy of *B. dorsalis* and *B. curcubitae* was presented by Prof. Ji Qing'e, Fujian Agriculture and Forestry University. Mass rearing techniques, methods for sexing and sterilizing males as well as tools for their release in the orchards have been developed. Furthermore, the mass production and release of several parasitoids specialized on the egg, the larval and the pupal stage is already implemented in order to achieve an „area-wide integrated biocontrol". Prof. Dr. Li Zhihong, China Agricultural University gave an overview on plant quarantine practice and phytosanitary techniques in China regarding prevention of entry and exit of fruit flies. Currently, there are 5 genera and 7 species under quarantine regulation for entry and domestic transportation in China, whereas three species (*B. dorsalis*, *B. curcubitae*, *D. suzukii*) are of concern regarding exportation. There are 170 bilateral quarantine protocols on fruit export and import between China and other countries, e.g. on *D. suzukii* between New Zealand and Australia. Techniques for risk assessment (climatic modeling), quarantine treatments (heat treatment, cold storage, irradiation), surveillance (especially trapping) and identification (barcoding) are implemented or under development. Dr. Li Zhihong stressed the need for more collaborative research on the invasion mechanisms of *D. suzukii*. Dr. Heidrun Vogt, JKI – Institute for Plant Protection in Fruit Crops and Viticulture, summarized the history of the rapid invasion of *D. suzukii* in Germany and presented current research findings on seasonal occurrence and dispersal behaviour of this species within different natural habitats, cropping systems and also migration on the landscape level. Furthermore, current research topics regarding biology, (chemical) ecology and control strategies were addressed. Dr. Monica Frosch, Hessen Plant Protection Service, evaluated the damage risk for particular fruit crops (mainly sweet and sour cherries, raspberries and blackberries, black currants, other soft fruits) and wild host species (23 out of 46 tested species positive) in the German situation. Furthermore, she reported on damage extent and economic impact of the serious *D. suzukii* infestation in 2014, resulting in crop losses of up to 4 million Euros in different fruit production areas. Sandra Müller, Chamber of Agriculture Northrhine-Westphalia, characterized in her talk the peculiarities of fruit growing in Germany (mainly small structured, highly diverse production, partially protected in tunnels) and outlined the potential impact of SWD on future cropping patterns taking into account high investment in protective measures (netting etc.), changing varieties and abandoning minor crops (e.g. elderberry). Dr. Günter Hoos, Rhineland-Palatinate Research and Service Centre for Rural Areas, summarized the particular situation in grape, where high losses due to SWD infestation had been reported on several varieties in 2014. Damage on grape by *D. suzukii*, but also other factors led to the propagation of yeast, bacteria, the fast collapsing of the grape and the production of acetic acid which caused deterioration of wine. Colour, degree of ripeness (sugar content), fruit damage (wasps, birds, powdery mildew, others) and splitting (heavy rain) could be identified as predisposing factors for *D. suzukii* attack and consequently, measures for prevention were developed and communicated to farmers. Dr. Kirsten Köppler, Centre for Agricultural Technology (LTZ) Augustenberg, reported on current control strategies being implemented in Germany, including the relevant plant protection products and particular instructions for their application in the different crop systems in the framework of the „emergency use" authorization. Biotechnical solutions (mass trapping, netting, bait sprays, attract and kill strategies) are still not sufficiently effective and intensive research activities are needed for their optimization. Recommendations for fruit growers including harvesting, sanitation and pruning measures have been developed.

In China, *D. suzukii* has been reported as pest on cherries only recently (presentation of Prof. Niu Changying, Huazhong Agricultural University) and mainly from late varieties (Haye et al., 2016). It is considered as minor pest and the main damage was observed in bayberry plantations in the Yunnan Province. Prof. Xiao Chun, Yunnan

Agricultural University, informed in his talk about the problems caused by SWD in bayberry plantations in Yunnan Province, Shiping County. In this area, SWD became a serious pest, reaching damage levels around 60% on fruits in early 2000's when bayberry growing had peaked at more than 8000 ha. Comprehensive research activities by the YAU led to pest management, based on monitoring, mass-trapping, attract and kill with poisoned fruits, orchard sanitation and post-harvest spraying of chemical insecticides. A comprehensive technical bulletin (Tai and Fu, 2013) has been published and serves as basic manual for the farmers, supplemented by training courses. Prof. Xiao is also involved in the DROPSA-project, funded by the EU, where new strategies based on chemical ecology and biocontrol are to be developed. The aims and research objectives of DROPSA were presented in detail by Prof. Dr. Zhang Feng, MOA-CABI (Centre for Agriculture and Biosciences International/Chinese Academy of Agricultural Sciences (CAAS)) with particular emphasis on the work conducted by CABI China. One focus is the comparison of *D. suzukii* populations from Beijing and Yunnan province concerning their population dynamics (peak in July in Beijing, no serious damage in cultivated fruits in this region), climatic preferences (Beijing population more cold tolerant), host range, including wild plants (Rosaceae are favourite hosts), chemical ecology and natural enemies. These research activities are tackled in close cooperation with CABI Switzerland, another partner within the DROPSA project. Dr. Annette Herz, JKI – Institute for Biological Control, reported on first results of biocontrol of *D. suzukii*, regarding the use of parasitoids and predators in Germany which accept this invasive insect as new host/prey. Resistance of *D. suzukii* against native parasitoids was observed, but several predatory species prey on accessible developmental stages (eggs, pupae, adults). Further investigations in cooperation with scientists from Japan (and hopefully also China in the future) on adapted natural enemies are underway, also regarding the search for effective pathogens like entomopathogenic fungi or viruses. Prof. Yu Yi, Shandong Academy of Agricultural Sciences, informed on his research with regards to genetic diversity of *D. suzukii* populations from different origins in China and also abroad. Thereafter, *D. suzukii* occurs in 22 provinces of China with 32 haplotypes. Infection rate of Chinese populations with the endosymbiotic bacterium *Wolbachia* amounted to 40 to 80%. Samples from the US and South Korea showed lower genetic diversity and no infection by *Wolbachia*.

This comprehensive knowledge in science and technology presented during the previous sessions formed the basis for the following discussion, which was chaired by Dr. H. Vogt (JKI), Dr. M. Roelcke (DCZ) and Dr. Yang Puyun (NATESC). Participants from both countries had prepared suggestions for future research. There was a high agreement on the most important topics, which was to be intensified in future cooperation and was incorporated into the Joint Declaration of Intent for further Research and German-Chinese Cooperation.

Results and proposed research areas – Joint Declaration of Intent for further Research and German-Chinese Cooperation – June 17, 2015

The participants agreed that this workshop was very successful as platform to exchange actual knowledge about *D. suzukii* and to define further important research topics. Based on the suggestions from the previous day, the following discussion priorities were set and focus was given to short term steps as well as long term research needs. These comprised the following principle topics:

a) Short-term, partly urgent, control measures: Technical methods, chemical control and biocontrol methods, mass-trapping, mutual dialogue on the extension services, exchange available information materials, possible Sino-German workshop in Germany in 2017.
b) Longer-term requirements for further research: Biology of *D. suzukii* as a base for the development of IPM technologies, biological control via identification, investigation and application techniques of natural antagonists in China and in Germany, ongoing knowledge transfer between science, extension service and growers, establishment of IPM demonstration fields, further technologies such as mass-trapping, as well as post-harvest-management. From the Chinese side strong interest was mentioned for sterile insect technology (SIT), though SWD is a very difficult target due to its high reproduction rate and wide distribution.

The results of the discussion were documented in a final joint declaration, stating that in order to address these issues and to achieve quick progress, new projects needed to be started in both countries and that knowledge exchange was to be continued. The participants also agreed to respect each other's intellectual property rights and that the envisaged cooperation within the framework of the DCZ would be without prejudice to the national competencies and administrative scopes of the respective authorities in the two countries.

Technical visit of red bayberry orchards and table grape vineyards in Shiping County, Yunnan Province – June 19, 2015

Red bayberry

Red bayberry (*Myrica rubra*) is the main fruit crop in Shiping County in the South-West Chinese province of Yunnan, situated 1,000 to 2,000 m.a.s.l. at the transition zone between southern subtropics and tropics, and 280 km south of the provincial capital Kunming. The fruit is eaten fresh and is also processed into sweets, jam, juice and wine (Fig. 2). It is also canned in syrup. The orchards in Shiping County extend widely over the hills, forming a connected growing area (Fig. 3). The fruit is harvested in May and June. The soil in the orchards is bare and there are only few other plants around which could serve as host plants for *D. suzukii*, e.g., *Solanum*

Fig. 2. Red bayberry fruits offered on a mobile market store, bicycle, together with mulberry and *Lotus* fruits (photos A. Herz, H. Vogt).

Fig. 3. Plantations of *Myrica rubra* (photos M. Frosch, S. Müller).

nigrum L., *Phytolacca americana* L. and *Lantana camara* L. along the farm roads.

In the visited eight year old red bayberry orchard, the colleagues from YAU had performed field trials in mass trapping combined with short harvesting intervals and hygienic measures since several years (Fig. 4) (Wu et al., 2007a, b). For monitoring, 1 trap per 0.33 ha was installed, for the control of *D. suzukii* 75 traps per ha.

The bait used contained different ingredients (e.g. sugar, vinegar, wine, fruit pulp of ripe fruits and water), of which the composition was not yet published. The bait was renewed every 3–4 days. Usually, all fallen fruit was removed from the orchard and the trees were picked completely, so that no overripe fruit remained in the orchard. At the date of our visit, these hygienic measures were not consequently implemented, which was explained by the low population level of SWD in 2015, caused by high temperatures above 30°C and very low humidity. We learned that there is no application of plant protection products on growing fruit, but post-harvest treatment of the plantation is undertaken by using insecticides with the active ingredients spinosad, abamectin or imidacloprid.

During the dry season in Shiping County (December to May) no or only few numbers of SWD are caught in monitoring traps. Most SWD are trapped from July to September. This could be explained by the beginning of the rainy season in June, thus the climatic conditions for development and reproduction of SWD is optimal. In addition, an extreme drought has been ongoing in SW China for several years. In combination with the relatively short ripening time of red bayberry (15–20 days

Fig. 4. *Drosophila* spec. flies on *Myrica rubra* (photo H. Vogt); trap with bait fluid (photo S. Müller); German experts talking with Prof. Xiao (photo H. Vogt).

from turning to red until harvest) and the low occurrence of other host plants, these facts might be an important reason for low SWD populations and consequently low fruit damage in 2015.

Unfortunately, the field trials of mass trapping in the years before did not include untreated control areas for comparison because of the risk of high financial loss. Nevertheless, the scientists agreed that it was important to consider untreated control plots in order to allow a better validation of the gathered data and conclusive results of scientific value.

Since the climatic conditions, the landscape and the kind of production in Yunnan are very different to German conditions, the experiences in pest management cannot be transferred directly, but are an important information to complement the state of knowledge of *D. suzukii*.

Table grape vineyard

Viticulture in China is in a phase of extremely dynamic development. According to the most recent OIV (The International Organisation of Vine and Wine) statistics, the People's Republic has close to 800,000 hectares of vineyards, putting it in second place worldwide, after Spain. Whereas in the past grapevines were planted primarily with the aim of producing table grapes, there is a continuous trend towards increased use for wine production, particularly using the traditional European varieties. For climatic reasons, the wine-producing regions tend to be concentrated in the north of the country, while table grapes are also planted further south.

There were no reports or discussion during the meeting about problems in viticulture related to the spread of *D. suzukii* in table grape vineyards. Thus it has to be assumed that the pest is not yet perceived as a problem in China in this type of agricultural environment.

Within the framework of the excursion, we visited a table grape producer cultivating approx. 400 *mu*[1] (approx. 27 ha) of vineyards, which were planted with a red (*'hei ti'*) domestic and a white grape. The white grape variety was 'Shuijing', which is widely planted in Yunnan province. The production area was situated in the valley close to the town of Shiping. The major part of the plantation was laid out in European style with cordon-type trellised vines, with a smaller section of pergola trellising, the farm was equipped with drip irrigation (Fig. 5). Some sections were equipped with foil roofing, in order to accelerate the harvest date. To ensure even ripening, the grape bunches were wrapped in paper covers open at the bottom for ventilation purposes, providing protection from rain and birds (Fig. 6). Harvest was in progress (Fig. 6). The planting density of approx. 10,000 vines per hectare produced a yield of up to 30 t ha^{-1}.

According to the grower this grape variety was not susceptible to *D. suzukii* which has so far not been observed in this location. Aphids and a scarabaeid beetle were the most important insect pests. Chinese scientists confirmed that no damage due to *D. suzukii* has been observed for grape varieties in other regions of China either. This could be attributed to the following reasons: the grape skins of the grape varieties planted here were relatively tough (a few grapes, which had not been harvested, could still be tested in this respect), the grapes were harvested at a point in time when aroma formation was still very weak, and there were no micro-splits in the grape skin which could encourage egg deposition. In addition, the methods used in the vineyard did not encourage a build-up in the population of vinegar flies. There was hardly any ground cover between the rows of vines, the grape zone was extensively defoliated, and all grapes

[1] 1 *mu* = 1/15 ha

Fig. 5. Vineyard (photo M. Frosch).

Fig. 6. Grape bunches wrapped in paper, discarded grape (photos G. Hoos); harvested grapes (photo H. Vogt).

that could not be utilized were removed from the vineyard after the harvest.

Conclusion: Because of the grape varieties cultivated in Yunnan, the harvesting time in early summer as well as of the physiological maturity level of the grapes, one can only deduce strategies for procedures in German viticulture to a very limited degree.

Visit of Yunnan Agricultural University (YAU) in Kunming, Yunnan – June 20, 2015

The last part of the stay in China was the visit of the YAU in Kunming (Fig. 7). This university was founded in 1938 and has currently about 20,000 students. 72 staff members and about 920 students belong to the School of Plant Protection with 4 departments: Agricultural Entomology, Pesticide Sciences, Plant Pathology and Plant Quarantine. Initially Prof. Ye Min introduced the Laboratory of Pesticide, Environmental Behavior and Chemical Ecology with its main tasks and focus of research.

The second part of the visit to YAU was a scientific colloquium of Prof. Xiao Chun's students, who work on pest organisms, especially on *D. suzukii*: In the first talk by Mrs. Liu Yan the first steps of collection, extraction and analysis of volatiles from different ripening stages of cherries were presented. The main intention of this study was the development of a bioassay to analyze behavioural reactions on the identified volatiles (i.e. feeding, calling, mating, oviposition) of *D. suzukii*. This study was still at the beginning. The second presentation by Mrs. Chen Xiao was about demography and life table studies: „Study on development of *Drosophila suzukii* at different temperatures". An experimental population was held in the lab and different development stages were kept under various constant temperatures. It was shown that with increasing temperatures from 15 to 27°C, the whole generation time (including the pre-oviposition phase) decreased. The generation time was slightly prolonged at 30°C, but fitness of adults and developmental rate until adult stage decreased. At 35°C no larval hatch was observed. For the investigated population the average lower temperature threshold was 7.5°C and the average upper temperature threshold was 26.3°C.

The next speaker, Mrs. Zhang Limin, presented data on the population dynamics of SWD in time and space including trapping results in the field. The main trap catches were observed in July and August and about 100% of the trapped population was reached in December. Factors influencing population dynamics and the carrying capacity of a habitat/the environment were discussed. The following presentation described the „Occurrence regularity of fruit fly in *Myrica rubra* orchard and integrated control techniques" with a comparison of the different *Drosophila* and two other fruit fly species in the orchard and in *Myrica* fruits. *D. suzukii* was observed as the dominant species in the orchard and only *D. suzukii* and *D. melanogaster* were found in the fruits. It was shown that the variety and the fruit maturity of *M. rubra* as well as the climatic conditions influenced the infestation level. The proposed integrated control measures were regular monitoring and control of fruit infestation, pruning and hygienic measures or postharvest treatments. Natural enemies of *D. suzukii* were also investigated in this study, but further research on them was needed. Until now four parasitoid species were found: *Ganaspis* spec., *Leptopilina* spec., *Trichopria drosophilae* and *Pachycrepoideus vindemmiae*. In the last talk of this scientific session Dong Wenxia presented results of electro-physiological responses of several pest insects to plant volatiles. In a first electroantennogram *D. suzukii* responded to cis-hexen-1-ol.

All speakers showed a high scientific level. The general results confirmed the experiences with *D. suzukii* which were made in Germany until now. The discussed questions and demonstrated methods corresponded with those in other research laboratories and working groups. Therefore, collaborations and scientific exchange could

Fig. 7. Visit of laboratories at Yunnan Agricultural University; participants in the colloquium (photos C. Xiao).

lead to the development of more effective sustainable and integrated control strategies of *D. suzukii*.

Conclusive considerations on the actual situation in SWD management in fruit production in China and in Germany

M. rubra, the Chinese or Red Bayberry, is certainly not the most important fruit crop in China in respect to the production volume, but it is of significant economical value especially in the provinces south of the Yangtze River. Production in China has increased dramatically over the past decade. In Shiping County, the planting area is of 8.000 ha (production value = 220 million € yr^{-1}). Many efforts have been realized to control *D. suzukii* with different methods as described before. The measures undertaken are very labor intensive. Regarding this crop, this is of no problem as very good prices can be achieved especially at the beginning of the harvest period. During the harvesting period application of plant protection products does not occur on the *Myrica* trees in the province of Yunnan, but post-harvest treatment is recommended. The production is called „green food", which is an intermediate Chinese standard between IPM, biocontrol and organic farming. As Prof. Xiao Chun stated, the quality of the fruits is very important and residues of plant protection products in the fruits are not accepted. The measures taken seem to be well-suited for the visited region. The original intensity of attack decreased from 60% (in the year 2000) to 1% nowadays. The reason for this reduction was not scientifically evident yet as the results of the monitoring in „treated" orchards could not be compared to „untreated" for the reasons mentioned before.

Sanitation measures certainly play a big role for the reduction of SWD populations. As mentioned before, the *Myrica* orchards form rather uniform extended plantation areas with no or very few other fruit species which could serve as host. In addition the recommended measures are presumably executed at the same time. The severe drought observed in the past years in a large part of South-West China might as well have been a natural factor for the reduction of the SWD population. In grapes, *D. suzukii* seems to be of little significance. The German scientists received no information on the fly's impact on production of cherry and blueberry in China. Apparently some infestation has been observed locally in cherries and a recent publication reports about increasing damages to cherry orchards due to climate-dependent delayed maturation of fruits and to the increase in the production area for late maturing cherry varieties (Haye et al., 2016). Despite its widespread distribution, *D. suzukii* does currently not seem to be of great economic importance for the entire fruit production in China. The reason for this could be the mentioned factors such as climate, especially extended dry periods, the presence of established natural enemies and the labor-intensive control measures. Probably the cultivar may also have an influence. So far, there are more than 300 *Myrica* cultivars in China.

Because of many differences to the situation in Germany, such as host plants, huge uniform plantation area, short fruit season, labor intensive hygiene measures as well as climate and population dynamics of *D. suzukii* it is not possible to transfer the Chinese strategies applied in the *Myrica* plantations directly to German cropping systems. However, components of the management strategies, such as monitoring, hygienic measures, development of bait and kill techniques, safe integration of insecticides, intensive consultation of the farmers etc., are also followed in Germany. Concerning the sanitation methods, in Germany these include pruning of the plants (i.e. plantations, especially raspberries and blackberries, should be not too dense, but well ventilated). For grapes defoliation around the ripening fruits is an important option, as *Drosophila* prefers to avoid bright sunlight and high temperatures. With regard to strict harvest of all fruits, especially infested ones and their elimination from the orchard, this is difficult to implement in Germany, as this is extremely labor intensive and would lead to high additional costs and drastically lower the profitability.

Post harvest treatment is always recommended in China in order to drastically reduce the population. It remains uncertain whether this actually does affect the population of the following year as weather conditions during the following 10 months have significant effects on the development of the insect. Mass trapping has not revealed to be effective neither in Germany nor in other European countries up to now. It could delay the infestation in some cases, but would not prevent economical damages, especially under high population pressure. The German landscape scenario in many fruit producing regions with small production plots and a mosaic of hosts habitats (cultivated and uncultivated) as well as refuge areas (hedges, forests) also is an issue, as it offers *D. suzukii* ideal survival and reproduction conditions and leads to steady reinfestation of cultivated crops.

Mass trapping or Bait and Kill (ideally Attract and Kill) might be options in future, but these methods need highly attractive and specific attractants. Prof. Xiao explained that they worked on their bait for 10 years and he still sees the need for optimization. It might also be necessary to adapt the mixtures with regard to the host fruit to be protected. Concerning pheromones, no pheromone production is known in *D. suzukii*, in contrast to the production of the pheromone cis-11-octadecenyl acetate (cVA) in the *D. melanogaster* group, where it plays a role in sexual and social behaviours. According to recent findings, *D. suzukii* males can still detect cVA inspite of reduced receptors, but the chemical functions as repellent, not as attractant (Dekker et al., 2015). Hence, the search for attractants is focused on food and host fruit volatiles. On the other hand, repellents are searched for.

Actually in both countries, SWD management is mainly based on technical methods (monitoring, sanitation, i.e. pruning, short picking intervals, as far as possible complete picking of ripe and rotten fruits, cooling of fruit as post harvest treatment) and integration of insecticides. In China mass trapping is used as described above, while

in Germany protecting the crops with nets is being investigated as an option for some crops, although it is very cost intensive.

General conclusion from the workshop and the excursion

The workshop acknowledged the complexity of the pest insect *D. suzukii*. Its damage potential is influenced by a series of factors such as climate, cropping structure, availability and diversity of host plants (cultivated crop plants and non-crop ones) in time and space, antagonists, and landscape. While the growing conditions and the damage extent in China differ distinctly from those in Germany, the main research topics and the basic recommendations for control are quite similar.

Based on the excellent understanding of the participants both on a scientific and personal level and the urgent need for intensified research to find solutions for the severe problems caused by *D. suzukii*, the participants established an intensive professional discussion and documented the main research needs as results from the workshop in a Joint Declaration as mentioned above. The knowledge exchange is to be continued, e.g. by the exchange of scientific publications, leaflets and practical information. The application for funding of new projects between both countries (for personnel exchange and for research) is currently under discussion.

Some of the Chinese participants from the YAU and the CAAS are involved in the DROPSA-Project in which also the JKI – Institute for National and International Plant Health in Braunschweig takes part as one of 21 EU partners. Chinese scientists from the China Agricultural University (CAU) in Beijing have participated in the International Plant Protection Congress (IPPC) in August 2015 in Berlin. Together with international colleagues, the JKI has organized two sections and a workshop on *D. suzukii* at the IPPC. A second German- Chinese expert workshop on *D. suzukii* is planned for 2017 in Germany.

Acknowledgements

The workshop and the excursion were perfectly organized. We thank all involved institutions and persons, the German Federal Ministry of Agriculture (BMEL), the Chinese Ministry of Agriculture (MOA), the Embassy of the Federal Republic of Germany in Beijing, the German-Chinese Agricultural Center (DCZ), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, the Foreign Economic Cooperation Center (FECC) and the National Agro-Technical Extension and Service Center (NATESC).

We thank all involved Chinese colleagues and experts for the perfect organization, in particular Mr. Yu Ge and Mr. Xie Dongsheng of FECC and Dr. Yang Puyun of NATESC, and for the excellent scientific exchange, including the most valuable visit to the *Myrica rubra* fruit production area in Shiping County, Yunnan Province and to the Yunnan Agricultural University in Kunming, under the perfect guidance of Prof. Xiao Chun, and last but not least for the overwhelming hospitality.

References

Asplen, M., G. Anfora, A. Biondi, D.-S. Choi, D. Chu, K.M. Daane, P. Gibert, A.P Gutierrez, K.A. Hoelmer, W.D. Hutchison, R. Isaacs, Z-L. Jiang, Z. Kárpáti, MT. Kimura, M. Pascual, C.R. Philips, C. Plantamp, L. Ponti, G. Vétek, H. Vogt, V.M Walton, N. Desneux, 2015: Invasion biology of spotted wing Drosophila (*Drosophila suzukii*): a global perspective and future priorities. J. Pest Sci. **88**, 469-494.

Briem, F., A. Eben, J. Gross, H. Vogt, 2016: An invader supported by a parasite: Mistletoe berries as a host for food and reproduction of Spotted Wing Drosophila in early spring. Journal of Pest Science, DOI: 10.1007/s10340-016-0739-6.

Briem, F., K. Köppler, M. Breuer, H. Vogt, 2015: Phenology and occurrence of Spotted Wing Drosophila in Germany and case studies for its control in berry crops. IOBC-WPRS Bulletin **109**, 233-237.

Cini, A, C. Ioriatti, G. Anfora, 2012: A review of the invasion of *Drosophila suzukii* in Europe and a draft research agenda for integrated pest management. Bull. Insectol. **65**,149-160.

Dekker, T., S. Revadi, S. Mansourian, S. Ramasamy, S. Lebreton, P.G. Becher, S. Angeli, O. Rota-Stabelli, G. Anfora, 2015: Loss of *Drosophila* pheromone reverses its role in sexual communication in *Drosophila suzukii*. Proc. R. S. Biological Sciences 282, 20143018, http://dx.doi.org/10.1098/rspb.2014.3018.

Haye, T., P. Girod, A.G.S. Cuthbertson, X.G. Wang, K.M. Daane, K.A. Hoelmer, C. Baroffio, J.P. Zhang, N. Desneux, 2016: Current SWD IPM tactics and their practical implementation in fruit crops across different regions around the world. J. Pest Sci., DOI: 10.1007/s10340-016-0737-8.

Hoffmann, C., 2015: Reflections about the Pest Status of *Drosophila suzukii* (SWD) in German Viticulture, Proceedings of the XXVIII. Berlin, International Plant Protection Congress, p. 75.

Ioriatti, C., V. Walton, D. Dalton, G. Anfora, A. Grassi, S. Maistri, V. Mazzoni, 2015: *Drosophila suzukii* (Diptera: Drosophilidae) and its Potential Impact to Wine Grapes During Harvest in Two Cool Climate Wine Grape Production Regions. J. Econ. Entomol. 1-8.

Kanzawa, T., 1939: Studies on *Drosophila suzukii* Mats. Kofu, Japan, Yamanashi Agricultural Experimental Station, Report.

Köppler, K., H. Vogt, 2013: Die Kirschessigfliege, *Drosophila suzukii*, in Deutschland – wie geht es weiter? Bericht von der ersten Sitzung der Arbeitsgruppe „Kirschessigfliege". Obstbau 3, 155-158.

Köppler, K., H. Vogt, 2015: Versuchsergebnisse zusammengetragen und Vorgehen für 2015 abgestimmt – 3. Treffen der Arbeitsgruppe Kirschessigfliege: Wertvolle Zusammenarbeit über die Landesgrenzen hinweg. Obstbau 5, 318-320.

Tai, Y,. Y. Fu, 2013: Essigfliegen, die *Myrica rubra* befallen – Befallsverlauf, vorbeugende und kurative Maßnahmen. Kunming, China, Broschüre für Landwirte, 43 S.

Vogt, H., P. Baufeld, J. Gross, K. Köppler, C. Hoffmann , 2012a: *Drosophila suzukii*: eine neue Bedrohung für den Europäischen Obst- und Weinbau. Bericht über eine internationale Tagung in Trient, 2. Dezember 2011. Journal für Kulturpflanzen **64**, 68-72.

Vogt, H., C. Hoffmann, J. Gross, 2012b: Ein neuer Schädling, die Kirschessigfliege, *Drosophila suzukii* (Matsumura 1931), bedroht Obst- und Weinkulturen. Entomologische Nachrichten und Berichte **56**, 191-196.

Vogt, H., K. Köppler, 2014: Bericht über das 2. Treffen der Arbeitsgruppe Kirschessigfliege. Journal für Kulturpflanzen **66**, 110-12.

Vogt, H., 2014: Rasante und folgenschwere Ausbreitung eines für den Obst- und Weinbau neuen invasiven Schädlings: Die Kirschessigfliege, *Drosophila suzukii* (Matsumura). Mitt. Dtsch. Ges. Angew. Ent. **19** (Entomologentagung in Göttingen, 18.-21. März 2013), 211-221.

Wu, S.R, J.T. Li, Z.Y. Li, M. Tao, Z.Q. Xu, G.L. Ma, C. Xiao, 2007a: A comparative study on effects of attracting fruit flies by different methods in red bayberry orchard. Journal of Mountain Agriculture and Biology, 26 (4), 365-368. *(Englische Übersetzung liegt den Autoren vor)*..

Wu, S.R, H.K. Tai, Z.Y. Li, X. Wu, S.S. Yang, W. Sun, C. Xiao, 2007b: Field evaluation of different trapping methods of cherry fruit fly, *Drosophila suzukii.* Journal of Yunnan Agricultural University **22** (5), 776-778.