## New insights into the ecology of Drosophila suzukii in Germany and its pest status

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Since its invasion to Germany in 2011, D. suzukii, commonly named Spotted Wing Drosophila (SWD), has become the most dangerous pest in stone and soft fruit. It is causing enormous economic losses. With the aim to develop sustainable control techniques, profound knowledge on SWD biology is indispensible. Main research areas at the JKI are: SWD phenology, GIS-based risk analysis, overwintering, feeding ecology, susceptibility of cherry varieties, impact of surrounding vegetation on pest pressure in orchards, effects of extreme heat and dryness, plant compounds, insecticides, bait mixes for traps, exclusion netting. Concerning SWD phenology, all-season higher captures occur in the landscape compared to orchards. Flies are active at mild days in winter. Lowest activity/population density is observed from April to June, highest in November to December. Our monitoring showed that in autumn and winter flies are preferably found in the canopy of evergreen trees like pines. In contrast, flies disappear with leaf fall in deciduous trees. Adults overwinter as winter morphs. We examined flies from our monitoring traps year round with regard to ovarian development, wing length and coloration. Compared to summer morphs, winter morphs are darker, have up to 0.5 mm longer wings and females do not produce eggs. In our region winter morphs occur from October to June, indicating their long life span. Egg production in winter morphs starts mid-March to April. Abiotic factors and food resources are most crucial for winter survival and early hosts in spring influence population built-up. We proved that mistletoe berries (Viscum album) are first host fruits in spring. Cherries play a major role for population built-up from May onward. Immigration into cherry orchards takes place in March to April each year, long before fruits are available. Oviposition starts in light red fruits and infestation increases quickly. SWD stays present in cherry orchards at least until leaf fall. Other cultivated fruits in the course of the year (raspberries, blackberries, blueberries, plums, elderberries, etc.) are used as reproduction hosts until late autumn. Temperatures above 30°C and low humidity have shown to slow down population built-up significantly. We demonstrated this by exposing flies to heat waves in a climate chamber. As a technical approach for SWD control the JKI is coordinating a demonstration project „Exclusion netting for managing Spotted Wing Drosophila in fruit crops“, which started in 2017.

## Ecological status of Spotted Wing Drosophila (SWD), Drosophila suzukii, in Shandong Province, China

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Drosophila suzukii (Diptera: Drosophilidae) is able to lay eggs and feed on healthy ripening fruit. In this study, sugar-acetic acid-ethanol solution and sticky traps with different colours were optimized and selected to monitor the phenology of D. suzukii. The results showed that flies had strong chemotaxis to sugar-acetic acid-ethanol solution after adding yeast and cherry fruits. Black sticky trap can attract more D. suzukii in the field; however, in the experiment of phobophototaxis we found that D. suzukii had stronger phobophototaxis to violet, blue and green light than to the other colours. D. suzukii and other Drosophila species were monitored in coastal (City of Weihai, Yantai, Rizhao) and inland region (City of Taian, Laiwu) of Shandong province. The number of flies in coastal region was higher than that in inland region due to the warm and humid climate. D. melanogaster and D. suzukii were the main Drosophila species and occurred at 13th May and 23th May, respectively. The number of D. suzukii was higher than D. melanogaster from 23th May to 1st June. In conclusion, the ecological niche of D. suzukii was different from other Drosophila species. Green and black can be the best selection for the colour of traps to monitor D. suzukii combined with the laboratory and field trial.

## Using Drosophila suzukii as a comparative model for studying olfactory evolution.

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It has been demonstrated that Drosophila suzukii is capable of attacking ripening fruit, making it a unique species within a fly family named for their attraction towards the fermentation products associated with rotten fruits, vinegar, and yeast. It also has been hypothesized that D. suzukii is more attracted to the volatiles associated with the earlier ripening stages of fruit development, and in turn, that D. suzukii is less attracted to fermented food resources, especially when compared with D. melanogaster. Here, we demonstrate that D. suzukii and its close relative D. biarmipes are in fact more sensitive to volatiles associated with the fruit-ripening process. Our data also provide evidence for a similar evolutionary specialization to that observed within Scaptomyza, a close relative to D. suzukii, which possesses a serrated ovipositor and are leaf-miners. Moreover, we have unpublished evidence that the compound eye and visual activity of D. suzukii is far superior to that of D. melanogaster, a visual adaptation that may again support arrival at host fruit prior to ripening and the release of the full odour bouquet.

## The attractivity of bayberry fruit volatiles to the vinegar fruit fly

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Chinese bayberry, Myrica rubra, is one of the most favourite hosts to vinegar fruit fly, Drosophila suzukii, which causes serious damage to Chinese bayberry fruits. The objective of our study was to identify new attractants for D. suzukii from Chinese bayberry volatiles. The bayberry fruit volatiles were collected by headspace absorption and identified by GC-MS, and the electro-physiological responses of D. suzukii to bayberry fruit volatiles were measured by coupled GC-EAD. The behavioural responses of the flies to bayberry fruits and their volatiles were tested in Y-tube olfactometer, and the attractivity of the synthetic compounds mixture was also confirmed by field trapping expe-

riment. The result showed that 46, 35 and 17 compounds were identified from ripe, half-ripe and raw bayberry volatiles, respectively. β-Caryophyllene was the dominant compound in bayberry fruits at the different ripening stages, and most esters were released from the bayberry fruits at the ripe stage. Five volatile compounds, namely methyl 3-hexenoate, methyl 2-hexenoate, ethyl 2-hexenoate, α-ylangene, α-caryophyllene, and an unknown chemical in the bayberry headspace samples, elicited GC-EAD responses from the female flies. Four synthetic compounds, namely 3-hexenoate, methyl 2-hexenoate, ethyl 2-hexenoate and α-caryophyllene and their mixtures could attract the females. The mixture was attractive to both males and females in a sandal wood orchard (Osyris wightiana, Santalaceae). It suggested that the mixture of methyl 3-hexenoate, methyl 2-hexenoate, ethyl hexenoate and α-caryophyllene is a good candidate for attracting D. suzukii.

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## New approaches to apply plant compounds in control strategies: Screening for natural compounds against Drosophila suzukii

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Drosophila suzukii (Diptera: Drosophilidae) invaded Germany in 2011 and has become a major economic pest in soft and stone fruits. It is highly polyphagous and oviposits in ripe, undamaged fruits. Larvae feed on the fruit pulp, infested fruits collapse quickly, and leave no tolerance threshold for fruit infestation. Since the currently practiced calendar-scheduled treatment with insecticides is not a sustainable means of pest control, alternative monitoring and management options are urgently needed. Behaviour based strategies are often species-specific and require attractive or repellent substances. In order to identify potentially applicable compounds, we tested eight synthetic plant substances from different chemical classes and eight essential oils for toxic, feeding stimulant or – repellent effects on adult D. suzukii. Male and female flies with an age of 7–9 d were used in the assays. Compounds were sprayed on bottom and sides of test cups in 2%, 4%, 6%, 8%, and 10% emulsion in lecithin/water. Ten insects were released into the cups after complete evaporation of the spray cover. The lecithin/water solution served as control. Mortality through contact with treated surfaces was evaluated after 1 h, 4 h, and 24 h. Six replications were conducted for each concentration and compound. Capillary feeding assays were used to determine feeding stimulation or inhibition compared to a control without the test compound. Test insects were previously starved and kept with only water for 20 h. Five females (7–9 d old) were used in each test vial. Blue dye was added to the liquid diet to detect consumption of the food mix by each of the test insects. Substances were offered in 0.01%, 0.1%, and 1.0% solutions in the capillaries. After 4 h the amount consumed was measured for each group of flies. Ten replications were evaluated for each concentration and compound. During the assays, cups and vials with capillaries were maintained in a climate chamber. Purity of all substances was verified and composition of essential oils was analyzed by GC/MS (Hewlett Packard 890 II/Finnigan Mat SSQ 7000). Several potentially toxic and behaviour modifying compounds were identified. Farnesol and lemongrass oil had lowest contact toxicity and were strongest feeding stimulants, whereas cinnamon oil and eugenol showed highest contact toxicity and strongest feeding repellency. These substances will be further tested in behavioural assays. Their use as bait components in attract &kill or as volatiles in push-pull strategies will be investigated.

## Behavioral rhythms of Drosophila suzukii and Drosophila melanogaster

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Drosophila suzukii and Drosophila melanogaster feed on various fruits, causing great economic losses. In order to find the optimum time for controlling D. suzukii and D. melanogaster, the daily rhythms of oviposition, egg hatch, pupation, adult eclosion, copulation, and feeding of these two pests were studied. We found the circadian rhythm of D. suzukii oviposition to have a single pattern with a peak from 20:00–24:00, while the peak oviposition of D.melanogaster was from 16:00–4:00 (the next day). Neither D. suzukii nor D. melanogaster showed a daily pattern of egg hatch. The single peak of egg hatch for D. suzukii occurred 24–32 h after oviposition, while that for D. melanogaster followed a bimodal pattern with the first peak of egg hatch from 0–4 h after oviposition and the second from 32–36 h after oviposition. Pupation in D. suzukii showed a single peak from 8:00–16:00, while in D. melanogaster pupation followed a bimodal pattern, with peaks from 4:00–8:00 and 12:00–20:00. Eclosion of D. suzukii adults followed a unimodal pattern and generally took place from 0:00–8:00, while that of D. melanogaster also showed a single peak, generally from 0:00–12:00. Meanwhile copulation of D. suzukii, which showed a bimodal pattern, was concentrated from 0:00–12:00 and 20:00–24:00 (the next day), while copulation of D. melanogaster showed a single peak, generally from 0:00–12:00. Both D. suzukii and D. melanogaster had a preference for feeding in light, and in a 24 h photoperiod the percentages of feeding insects were 80.8 and 81.1, respectively.

## Effect of selected fungi from diet on the growth and development of Drosophila suzukii (Diptera: Drosophilidae)

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Drosophila suzukii (Diptera: Drosophilidae) is one of the very few Drosophila species which are able to lay eggs and feed on healthy ripening fruit. Adults and larvae are all able to obtain the nutrition in the decaying food, which will generate many microorganisms. However, the relationship between D. suzukii