Control strategies for *Drosophila suzukii* management in fruit crops in Germany

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The Spotted Wing Drosophila (SWD) with its highly broad host spectrum is one of the most serious pests in Germany in fruit crops since its first record in 2011. The most susceptible crops are all stone fruits particularly cherries and almost all berry crops particularly raspberries and blackberries. Infestation levels can reach up to 100 % without any regulation or control measures. Even if control measures were applied, losses can reach an economical level, where harvest must be ceased. Depending on population development and climate, infestation pressure varies between different periods during one season or between different years. For most threatened crops in Southern Germany potential control periods of SWD are from May (strawberries and cherries) until October (raspberries, blackberries). Hence, growers cultivating different crops have to face a huge challenge in plant protection. For short term control, different insecticides are registered. In stone fruits, only annual authorizations for emergency uses are allowed (article 53 EU-regulation 1107/2009). In 2017, spinosad (SpinTor) and lambda-cyhalothrine (Karate Zeon) could be used in all stone fruits. In sweet and sour cherries as well as plums cyantraniliprole (DuPont Exirel) could be applied additionally. In all berries, spinosad is registered according to a regular authorization against SWD. Furthermore, the application of Karate Zeon is possible in raspberries, blackberries, currants and blueberries. DuPont Exirel can be used only in currants and blueberries according to an article 53-authorization. Pros and cons of chemical control have to be taken into account. This includes varying efficacies against certain SWD stages, different maximum residue levels and following pre-harvest periods. Additionally rain fastness as well as side effects on honey bees or predatory mites vary between the different insecticides. Therefore, other measures are necessary to decrease the population and infestation pressure of SWD in fruit crops. The general recommendations to growers focus on preventive measures as well as cultivating techniques such as netting, regular monitoring of SWD, consequent pruning, regular mulching, short harvesting intervals, complete harvest, consequent sanitation measures and quick refrigerating and processing of fruits. All these control and preventive measures increase cost for fruit production which can be a risk for the economic feasibility of farms. This requires an economically as well as environmentally sustainable control strategy against this serious invasive pest.

Field demonstration of control techniques of *Drosophila suzukii* in China

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From year 2015 to 2017, four pilot sites (two for cherry and two for bayberry) were selected as demonstration areas for controlling *Drosophila suzukii*. The techniques demonstrated were monitoring of *D. suzukii* in orchards including seasonal fluctuation and peak periods, techniques of attract-and-kill adult flies and removal of dropped fruits. In addition, two field experiments were conducted with the aim to test the efficiency of different wine lures trap, different colour trap and chemical control on population of *D. suzukii* in orchards. The following conclusions can be given based on the field demonstrations: (1) Using the sugar and vinegar liquid is effective for the control of *D. suzukii*. Farmers can use simple traps for monitoring, predicting, controlling and trapping fruit flies. (2) The rotted fruit can attract the vinegar flies, so it can be added to the sweet and sour wine solution to increase the control effect. (3) The tests with colour traps for *D. suzukii* in red bayberry orchard show that blue and yellow are more effective than green and red, but this result needs further verification. (4) Attraction by different wine lures for *D. suzukii* in red bayberry orchard show that there was no significant difference between the different ratios of white wine and vinegar. (5) The larvae can pupate in the fruit and soil, so the removal of dropped fruits on the ground can effectively reduce the number of fruit flies in the orchard. (6) It is suggested to suppress the population of *D. suzukii* around the orchards. (7) The field test with the chemical compound of ethyl polybacteria show that chemicals can reduce the populations of *D. suzukii* in the orchard, but in general chemical sprays should not be used except really necessary. (8) Spray treatments of chemical pesticides can be applied at the population peak of the flies or after harvest, and it is necessary to improve spray methods in order to lower environmental pollution, including tminimize spray amounts and frequency so as to protect natural enemies.

Evaluation of soft fruit genetic resources for resistance to the Spotted Wing Drosophila (*Drosophila suzukii*)

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The Spotted Wing Drosophila (SWD) is an invasive insect which infests in particular thin-skinned berries as strawberries, raspberries, blackberries, blueberries, gooseberries and currants. Females of *Drosophila suzukii* attack fresh, ripe fruit by using their saw-like ovipositor to lay eggs under the fruits skin. The infestation occurs shortly before the harvest and the subsequent larval development makes the fruit unusable for marketing. A sustainable control of SWD can be only assured by the cultivation of resistant or at least less susceptible soft fruit cultivars. The aim of the project is the detection of genotypic differences in the susceptibility against the SWD in genetic resources of raspberry and strawberry. Resistant or less susceptible cultivars can then be used for breeding or recommended to growers in infested areas. In total, 19 summer-fruiting and 9 autumn-fruiting raspberry cultivars were evaluated for susceptibility against SWD in laboratory experiments with ten replicates per cultivar. For the infestation assay, 10 *D. suzukii* females and 5 males of an age between 4–6 days were released into a 125 ml plastic beaker with an aerated lid containing three fruits. The incubation temperature was 23 °C with a relative humidity of 65% and a light:dark regime of 16:8 h. After 24 h flies were removed and larvae were counted 5 days after infestation. There were significant different infestation rates between the cultivars evaluated. The summer-fruiting cultivars 'Cascade Delight' and 'Reflamba' showed the highest infestation rates with an average of 4.8 larvae per fruit and female. The lowest infestation rate were determined for the cultivars 'Dorman Red' and 'Glen Ample' with an average of 1.2 and 1.8 larvae per fruit and female, respectively. The autumn-fruiting cultivars 'Polana'

and 'Polka' showed an infestation rate of 2.9 larvae per fruit and female. Here, the infestation rate was significantly higher compared to the cultivars 'Autumn Best' and 'Aroma Queen'. However, these results were received from annual data and further research is needed. The evaluation of existing genetic resources is the first step of the identification of possible donors for further breeding purposes.

Natural compounds and their effect against *Drosophila suzukii*

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The recent worldwide spread as well as the polyphagous nature of the Spotted Wing Drosophila *Drosophila suzukii* Matsumura (Diptera: Drosophilidae) calls for efficient and selective control strategies. The use of insecticides is one option for management of this invasive pest insect. However, problems associated with the application of insecticides on ripening fruits include the consideration of preharvest intervals and pesticide residue levels as well as an exposure of nontarget organisms present on fruits. Biopesticides based on natural plant extracts offer an alternative to synthetic insecticides. Here, we report on laboratory bioassays using three different types of substrates allowing a thorough screening of four biopesticides (NeemAzal-T/S: a.i. azadirachtin; SpinTor: a.i. spinosad; Spruzit: a.i. pyrethrine; Piretro Verde: a.i. pyrethrine) and one synthetic insecticide (Mospilan, a.i. acetamiprid) for their effects against *D. suzukii* eggs, larvae and adults. An application of all products except for NeemAzal-T/S on water-apple juice agar before oviposition significantly reduced the number of eggs laid since adults died within the first 24 h after contact with the treated medium. A similar effect was visible if grape berries were treated with the products SpinTor and Mospilan. NeemAzal-T/S significantly reduced the number of larvae hatching out of eggs. Treatment of apple-nutrition medium after oviposition significantly reduced the number of individuals reaching the adult stage for all insecticides except for Spruzit. Moreover, the use of biopesticides in an attract-and-kill strategy is currently assessed in different set-ups. One option is an application of the biopesticide as small droplets onto leaves with the aim of adult feeding and an accordingly lower female fertility. A second option are traps containing a substrate for egg deposition, the biopesticide and an attractant. First results show that trap design matters and point to various avenues for the design of attract-and-kill strategies.

Sterile Insect Technique for *Drosophila suzukii*

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The Spotted Wing Drosophila or cherry vinegar fly (*Drosophila suzukii*) is native to Asia but has invaded other continents since 2008 and has spread throughout Europe. The females have a serrated ovipositor allowing them to penetrate the skins of intact ripening fruits to deposit their eggs, and the developing larvae rapidly destroy the fruits close to harvest. *D. suzukii* has a rapid life cycle and the larvae develop well beneath the fruit surface. This means that the use of pesticides is problematic and often not effective, first due to their restricted use close to harvest to protect consumers, and second because the larvae are deep enough inside the fruit to avoid contact. There are currently no cost-effective and environmentally sustainable pest control methods for this species available, resulting in extensive damage to fruit crops. The potential of new technologies as a basis for the urgently needed specific and long-term control of this species should be considered. In this respect, molecular technologies for eco-friendly control of agricultural pests have been developed for other species already and can be transferred to *D. suzukii*. Different technologies, from the development of transgenic conditional lethal systems to new genome editing methods like CRISPR/Cas, are compared and benefits and risks discussed.

Low temperature survival of German populations of *D. suzukii* in relation to food availability and *Wolbachia* infection

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Drosophila suzukii was first recorded in Southern Germany in 2011, including the viticultural area of Palatinate in the Southwest of Germany. Since 2012, regular monitoring is carried out at Neustadt/W., located within this region. Overwintering was studied at a hot-spot site in the following winters of 2013/2014, 2014/2015, 2015/2016 and 2016/2017. The results showed that overwintering does not take place in human shelters or in the ground. Active flies are readily captured when temperatures rise above 8°C during day and it is assumed that they hide on conifer trees. This way, they were able to survive conditions of −10°C and up to 11 ice days within a winter period. Males and females overwinter equally well. Therefore, we addressed the questions in laboratory trials whether German populations adapted to colder climates and whether sex or food supply have a major impact. For this we worked with two different populations: one old "laboratory" line (KEF4W) established in 2013 and one recent line (KEF8) established from the hot spot site just before starting the trials. PCR testing showed that KEF4W individuals where 100% infected with *Wolbachia* whereas all tested KEF8 individuals were negative. Flies were caged individually or in groups of 5 in 50 ml culture tubes. They did not survive without food supply for longer than 6 days at 10°C. However, on artificial diet they survived for more than 260 days at 10°C without loss. Therefore, all further experiments were carried out with food supply. At 3°C at constant darkness flies were still able to feed and survived more than 100 days (lethal time 80). Chill coma was observed at temperatures below 1°C and flies were no longer able to feed. At constant 0.5°C and −1°C maximum survival dropped to 20–25 days. Whereas cold hardened flies (1 week at 10°C) were still regarded as summer morphs, we also induced winter morphs experimentally by letting them develop entirely at 10°C. These winter morphs survived longer at −5°C (up to 6 days) than summer morphs. In conclusion, we observed neither a difference between *D. suzukii* populations nor an influence of *Wolbachia* on cold tolerance. At temperatures below 0°C females survived longer than males and winter morphs longer than summer morphs.