Host plant resistance of tomato plants to western flower thrips

Mirnezhad, M.

Chapter 7

Summary and conclusions

Thrips are the cause of substantial plant injury either through direct physical damage or, indirectly, by the transmission of viruses. In The Netherlands, thrips infestation of tomato plants leads to economic losses in the order of millions of dollars per year. Thrips are controlled basically by the application of pesticides, but the efficacy of these is often limited because thrips feed inside plant organs. Furthermore, most chemicals have a short-term effectiveness and frequent application is required. Such extensive use of pesticides has led to the development of pesticide resistance in thrips. Even more complicated is the problem of pesticide residues in marketable crops, which involves risks for human health, toxicity for beneficial insects and environmental contamination issues. Pesticide use could be replaced by the implementation of multiple control tactics in the framework of an integrated pest management (IPM) programme. Within this, an important strategy is the use of host plant resistance. Therefore, this thesis focused on host plant resistance of tomatoes to western flower thrips.

In the general introduction (Chapter 1) the importance of tomatoes as a globally produced vegetable and the role of thrips as a key insect pest worldwide is discussed.

Wild tomato plants are a source of resistance to pests. Therefore, WFT damage to wild and cultivated tomatoes was compared (Chapter2). Wild tomatoes proved to be significantly more resistant to WFT than cultivated tomatoes, which were all susceptible. Host plant resistance to WFT among wild tomatoes differed. The wild tomatoes *S. pennellii and S. hirsutum* showed the lowest amount of silver damage. The wild tomatoes had more trichomes but a lower dry mass compared to the cultivated tomatoes. Silver damage did not show a correlation with morphological plant characters. Host plant resistance to WFT was chemically based. Application of NMR-based metabolomics indicated that acylsugars were related to resistance to WFT while susceptible species contained significantly higher amounts of the alkaloid trigonelline. This may be the result of a metabolic trade-off favouring the production of acylsugars. These results thus show that wild tomatoes are a potential source of strategies for improvement of WFT resistance in cultivated varieties.

Insects can adapt to host plants. Genetic variation favours the prevalence of better adapted, more aggressive, biotypes, which may rise above the defensive properties of previously resistant plants. In Chapter 3, variation of genetics and performance of thrips from different commercially

grown glasshouse crops within the Dutch Westland and a lab culture kept on chrysanthemum were compared. Our study did not indicate the existence of different cryptic WFT species in the Netherlands. Genetic barcoding revealed that all WFT populations belonged to the "glasshouse" strain from California. AFLP analysis demonstrated genetic differences between WFT populations. The WFT lab population was genetically the most different from all other thrips' populations. Feeding and reproduction parameters in leaf disc and whole plant bioassays were scored as fitness parameters. We detected significant differences in thrips feeding among host plants and origin of thrips population. The wild tomato *S. pennellii* was the most resistant host for feeding and reproduction, coinciding with the findings of Chapter 2. The lab culture of WFT caused the most damage as compared to the other thrips populations. Reproductive success across plant species depended on the origin of the thrips population. The thrips lab culture on chrysanthemum obtained the highest level of reproduction on the host on which this lab culture was maintained. Differences among the other thrips populations were relatively small. The AFLP analyses and the interactions between host plant and WFT origin in thrips reproduction demonstrate the evolution of a lab biotype specialized in a particular host. This finding has potential relevance for future crop control and breeding programmes.

The phenylpropanoid chlorogenic acid (CGA) is the most ubiquitous natural plant dietary antioxidant. It is thought to prevent development of cancer and cardiovascular diseases in humans. At the same time CGA is reported to confer host plant resistance to insects. Due to its positive effects on human health and its negative effects on pests, CGA is the substance of choice for the study of the development of host plant resistance. In Chapter 4 transgenic tomatoes producing increased concentrations of CGA for dietary purposes were tested for thrips resistance. The results demonstrated that tomato plants with a double or triple amount of CGA did not show significantly lower thrips damage. Similarly, in *in-vitro* bioassays with fruits of these tomato plants, CGA did not affect survival or growth rate of thrips larvae. Possibly, the variation in CGA levels was not large enough to produce a detectable effect on thrips resistance. In addition, thrips resistance may be based on the additive or synergistic effect of CGA with another compound. The influence on the plants of environmental factors such as temperature and light as well as plant nutrition on CGA concentration should also be considered. Besides this, plants in diverse developmental stages may contain different amounts of CGA. It may be worthwhile to repeat experiments with higher concentrations of CGA and under different environmental conditions. So far, however, we have no indication that CGA plays a role in tomato resistance against thrips. This is surprising because CGA proved to have an effect on thrips resistance for a number of other plants.

Introgression lines (IL) represent an excellent platform to explore the genetics of multiple biological and chemical traits of agronomical importance. The wild tomato, *S. pennellii* was highly resistance to WFT as shown in Chapter 2. A set of 76 introgression lines between *S. pennellii* and the cultivated tomato *S. lycopersicum* was used to detect QTL associated with WFT resistance, secondary metabolites and their co-localization in Chapter 5. Nine potential QTL were identified for WFT resistance and 268 for metabolic traits. Neither multivariate data analysis nor correlation tests showed an association between thrips resistance and any of the detected metabolites including sugars and fatty acids as primary metabolites and phenolics and alkaloids as secondary metabolites. Acylsugars, which were related to thrips resistance as reported in Chapter 2, were not included in this study since QTL for these compounds using the same IL set have been previously reported in the literature. Trait mapping did not show consistent co-localization of WFT resistance and the profiled metabolites. Metabolic correlations were detected mostly within classes of compounds, e.g. lipids, amino acids and phenolics. Interestingly, QTL were identified for valuable phytochemicals, such as CGA and rutin. Particularly important were IL10-1 and 10-1-1, which respectively showed 2.6 and 4.4 fold increases in their CGA content as compared to the recurrent parent *S. lycopersicum.*

Sugars have acted as plant hormones that control gene expression and development processes in plants and sugar spraying of leaves has also been used in pest management of different plants. The effect of sugar spraying on resistance of cultivated tomato to WFT is discussed in chapter 6. Sugar sprays of fructose, glucose and sucrose were applied in concentrations of 0, 1, 10 and 100 ppm at the 2^{nd}, 3rd and 4^{th} plant leaf stage. The sugar treatments did not show significant effects on resistance of cultivated tomato (cv. Moneymaker) to WFT. Only fructose had a negative effect on WFT feeding when analysed separately. Successive experiments were run to confirm this result. Spraying of fructose in different concentrations and at different leaf stages did not produce any significant effects on resistance of tomato plants to WFT, although out of the 12 cases in which fructose spray was applied 10 cases showed less damage compared to the controls. It seems that under certain conditions there may be an effect of fructose- spraying on thrips resistance, although the reduction of damage is rather low. It is, therefore, unlikely that sugar spraying will make a significant contribution to pest management in tomatoes.

In conclusion: Neither increasing CGA content nor sugar spraying seem to be effective ways of inducing thrips resistance in tomatoes. The most promising road to take is to focus on the wild tomato, *S. pennellii*, which is rich in acylsugars, and which showed no detectable sign of thrips damage at all.

Epilogue:

Interestingly, in a batch of cultivated tomato seeds (cv. Moneymaker), we accidently detected a few seeds that produced highly resistant tomatoes. Resistance in these plants was based on the presence of trichomal glands producing polyphenols. Upon mechanical rupture of the glands, due to thrips movement, the polyphenols are oxidized and form polymer threads that accumulate around the thrips legs. This leads to immobilization and final death of the thrips. A preliminary study indicated that the production of fruits of this tomato was within the range of other cultivated varieties. We reproduced this tomato for three generations and all generations were highly resistant to thrips showing none to very little silver damage. Unfortunately, we do not know whether this tomato is a registered variety. Currently, the tomato in question is under further investigation in regard to its origin and resistance mechanism. The existence of such a thrips resistant line underlines the potential of host plant resistance as an important part of an integrated pest management approach to thrips control.