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Fauna of aphids and beneficials in fruit orchards and crop protection practices in orchards

Abstract

Using the chemical way to control aphids provokes generally negative side-effects on both the beneficial fauna and the application of biological controls (preventive and conventional) against aphids. This study was undertaken during a two-year survey (2014-2015), using visual observation technique, to provide new knowledge on biodiversity of aphids and beneficials in agro-ecosystems related to fruit orchards (managed and abandoned), which include pome (apples, pears) and stone (cherries, peaches and plums) fruit trees and associated flora in the eastern part of Belgium, particularly the Limburg province. Overall, 109 aphid species belong to 42 genera of the family Aphididae were recorded in the different habitats, on which 65 aphids were attacked by 45 parasitoid species (Braconidae & Aphelinidae). Regarding the predatory fauna that share aphids as food with parasitoids, more than 17 species belong to several families, mainly Coccinellidae, Syrphidae, Forficulidae, and spiders were recorded on fruit trees. Important presence of ants especially *Lasius niger* was observed associating with aphid colonies especially *Myzus cerasi* (on cherries), *Aphis pomi* and *Dysaphis plantaginea* (on apples). The observed fauna of aphids and beneficials associating with plant habitat are discussed in relation with parasitoid releasing strategies for integrated aphid management more efficient.

Keywords: aphids, parasitoids, fauna, Biological control, IPM.

Introduction

Many aphids (Hemiptera: Aphididae) are considered as serious pests for pome (apples and pears) and stone (plums, peaches, cherries and apricots) fruit tree crops in Europe. They can generate several types of economic damages on infested tree, i.e., distortion, drying and dropping of leaves, buds, flowers, fruits and even branches, encouraging the growth of sooty mould fungi, and virus spreading (over 200 plant viruses, Hogenhout et al. 2008). Because aphids have developed resistance to several insecticides (Devonshire et al. 1998; Foster et al. 2007) and because pesticide regulations are now stricter, biological control alternatives are increasingly investigated. Numerous insects including predators, parasitoids and entomopathogens fortunately exploit aphid colonies to survive. Many of these beneficials are currently used in preventive and curative releasings in order to control aphids on several cropping plants.

Beneficial fauna is however currently threatened by human-induced habitat alteration (Hunter 2007), e.g. pesticide applications, and the suppression of alternative food and shelter possibilities. Therefore, in the context of biological aphid control, to have an efficient management for aphids, a landscape diversification through habitat manipulation can be useful to create an appropriate ecological infrastructure offering suitable foods for aphid natural enemies, alternative prey or hosts, and shelter from adverse conditions (Olfert et al. 2002; Roschewitz et al. 2005; Bianchi et al. 2006; Alhmedi et al. 2007, 2011). Developing natural methods to control other pests attacking fruit trees can also help in reducing the negative effects of chemicals on aphid parasitoid releasing process which can enhance the biological control against aphids.

The nature of interaction between parasitoids and other beneficials is very important factor in determining the outcomes of aphid-parasitoid interaction. Aphid communities are rich in species of specialist and generalist arthropod predators that vary according to several biotic and abiotic factors, e.g. host plant species and phenology, season and weather conditions. Spiders, coccinellids, lacewings, anthocorids, nabids, predatory midges, syrphid flies, and ants are major components of the predatory guild associated with aphid colonies on host plants, while spiders, carabids, staphylinids, and ants are the most common taxa that exploit aphids on the ground (Frazer 1988; Sunderland 1988). Most of these predators are generalists and may also exploit plant-derived food or prey

on other herbivorous arthropods (Frazer 1988; Rosenheim et al. 1999), predators, including conspecifics (Rosenheim et al. 1993; Lucas et al. 1998), and parasitic wasps. All developmental stages of aphid parasitoids are vulnerable to predation. Eggs, larvae and pupae can be devoured once the aphid host has been captured, whereas foraging adults can be killed by generalist predators like spiders, nabides and ants. Völkl has conducted a series of studies of Aphidiine parasitoids foraging in nature, and has quantified the rates at which they fall prey to a range of generalist predators, including particularly spiders and ants (reviewed in Rosenheim 1998). Ants are among the important nautral elements that can positively or negatively influence the outcome of aphid-beneficial interaction. Ants at the same time protect and prey upon aphids (Billick et al. 2007). Understanding the nature of aphid-ant interaction and ant-natural enemy interaction can help us in developing beneficial (especially parasitoids) releasing strategy more efficient against aphid pests.

It remains unclear whether and under which ecological circumstances aphid parasitoids play a determining role in regulating aphid populations. In natural and managed ecosystems, aphid parasitoids usually have limited impact on aphid populations, with an incidence of parasitism of less than 10% (reviewed by Mackauer & Völkl 1993). Basically, three major elements have sustained the debate until present. A first argument is that, in many cases, hyperparasitism strongly impedes the actions of primary parasitoids (Rosenheim 1998). The second argument comes from the analysis of Mackauer and Völkl (1993) who have interpreted the consistent failure to observe density dependent parasitism in the field as a consequence of the foraging behaviour of aphid parasitoid females. The third argument comes from the intraguild predation by predators that share the habitat with parasitoids. Manipulate the spatial distribution and density of predators and ants by natural methods could help us in improving the efficacy of parasitoids against aphids. Parasitoid wasps (Hymenoptera: Aphidiinae), are considered as one of the most important natural enemies (specific to aphids) against aphid pests in agricultural system, and often more than one parasitoid species is needed to have efficient aphid control. The present research aims to realise a faunal investigation of aphids and beneficials in fruit orchards involving the associated flora in order to select efficient parasitoid candidates to control aphid pests on pome and stone fruit tree crops in Europe, in addition to the possibilities to apply parasitoid releasing against aphids in managed fruit orchards.

Material and methods

Field sampling

During the 2014 and 2015 growing seasons, the fauna of aphids and beneficials was investigated in orchards of apples, pears, cherries, plums and peaches and the associated flora growing either in or adjacent to fruit orchards located particularly in the eastern part of Belgium. The spatial distribution of ants in relation with aphids was also evaluated.

Sampling

Monitoring visits were daily performed from March to December to observe aphid species, beneficials, ants in fruit orchards involving weeds, shrubs, trees naturally grown both in and adjacent of fruit orchards. It was sometimes difficult to identify mummified aphid species, because some aphid characteristics necessary for identification were fully disappeared due to the mummification process in consequence of the parasitation of the aphids by the parasitoids. Therefore, and based on (in literature described) known parasitoid-aphid associations, it was assumed that parasitoid species sharing the same plant species with multiple (known host) aphid species had trophic interactions with these aphid species in equal proportion to the abundance of each aphid species on the shared plant. Fauna of predators and the distribution of ants were only investigated on fruit trees.

Samples of living and mummified aphids were collected from aphid-infested plants grown in 52 localities of the eastern zone of Belgium. One part of sampled mummies was kept in the laboratory on fresh plants until the adult emergence, and in transparent plastic containers and petri dish containing fresh part of the hosting plant. Living aphids were also kept in the laboratory on fresh plants for at least two weeks for any potential parasitism in the nature and collect the formed mummies and following the same process with those collected on plants from the field. We prepare the other part of parasitoid mummies (Figure 1) in carton tubes in order to send them to Viridaxis company for the possibility of commercial production. Each sample is labelled by combination of aphid-plant association and collection date and locality. In order to gain time, the parasitoid adults emerging in the laboratory were photographed and send to the Faculty of Biology, University of Belgrade (FBUB) team for a preliminary

identification. Subsequently, the specimens were sent in ethanol Eppendorf tubes to FBUB for the ID confirmation.

Figure1. Parasitoid mummies collected from the associated flora

Identification

All samples of parasitoids were identified by FBUB team on the basis of morphological identification keys (Pennacchio 1989; Tomanović et al. 2003; Kavallieratos et al. 2008; Starý and Lukáš 2009; Tomanović et al. 2014), and were also needed to be confirmed by molecular markers by FBUB team. Specimens of sampled aphids were preserved in ethanol 80% for the identification. All aphid specimens were identified at pcfruit vzw in collaboration with FBUB team using identification keys of Blackman and Eastop (1994, 2000, 2006) and of Taylor (1981). Associated flora, predators and ants were identified to the species or genus level using the standard identification manuals for each group.

Database containing a list of pests and diseases presence and current crop protection practices in apple, pear and cherry orchards in relation with phenological stages of the crops are provided by pcfruit vzw and presented in the annex 1.

Results

Aphid, beneficial and ant fauna

Frequency and diversity of aphids, beneficials and ants associated with various host plants were determined within cropping and non-cropping areas. A list of these

artropodes is represented in table 1 and 2. Parasitoid samples were collected from trees, shrubs and weeds in order to investigate faunal connections especially between parasitoids in different habitats and to increase the probability of finding of parasitoids interesting for both production techniques of Viridaxis and for preventive biological control of aphids on investigated fruit tree crops in Europe.

During the growing seasons of 2014 and 2015, among the observed 132 plant species infested by 109 aphid species, 78 plant species hosted populations of 294 effective aphid-parasitoid associations involving 66 aphid species and 45 parasitoid species in 52 abandoned and managed localities. Overall, *Aphidius ervi*, *Binodoxys angelicae*, *Ephedrus plagiator*, *Lysiphlebus fabarum*, *Praon abjectum* and *Praon volucre* were the most frequents on aphids which represented mainly by *Aphis fabae*, *Aphis pomi*, *Brachycaudus helichrysi*, *Brachycaudus cardui*, *Myzus cerasi*, *Dysaphis plantaginea* and *Hyalopterus pruni* were the most abundant and frequent on host plants. Among the 45 collected parasitoid species, based to their ecology and biology, several parasitoids are good candidates for biological control against aphids. Illustrations of some of them are presented in Figure 2 : *B. angelicae, D. rapae, L. gracilis, E. plagiator, P. volucre* and *P. abjectum.*

On fruit trees, population of 17 parasitoid species, mainly *Ephedrus persicae*, *E. plagiator*, *Aphidius matricariae*, *Aphelinus mali*, *P. volucre*, *P. abjectum*, and *B. angelicae* were recorded parasitizing on 10 aphid species, mainly *D. plantaginea*, *M. cerasi*, *B. helichrysi*, *Eriosoma lanigerum*, *A. pomi*, and *H. pruni*. More than 17 predatory species (including mites and spiders) belong to several families, mainly Coccinellidae, Syrphidae and Forficulidae, were recorded on fruit trees. Illustrations of some of them are presented in Figure 3.

The beneficials observed on pear trees were more related to the presence of other phytophagous arthropods like *Psylla* sp. pest and spider mites more than to the presence of aphids. Very low densities of aphids were recorded on pear trees, mainly *Aphis pomi* and *Aphis spiraecola*, on the end of the growing season. *Coccinella septempunctata*, *Harmonia axyridis*, *Episyrphus balteatus*, *Forficula auricularia* and *Aphidoletes aphidimyza* were the beneficials the most abundant during the infestation period of aphids on fruit trees. During May and June, persistent and considerable presence of *Forficula auricularia* individuals was observed on colonies of *Myzus cerasi* (on cherries) and *Dysaphis plantaginea* (on apples). Strong attack, but only from the second half of

May, by the predator *Aphidoletes aphidimyza* was observed on *M. cerasi*, *D. plantaginea*, *Aphis pomi*, *Hyalopterus pruni* and *Aphis fabae*. Ladybirds were early recorded on fruit trees; it was on the second half of April. Later on the second half of May for cherries and plums, and on the first half of June, dense presence of hoverfly larvae was observed on aphid colonies, especially *M. cerasi* (on cherries), *D. plantaginea* (on apples), *B. helichrysi* and *A. fabae* (on plums). On the other hand, the greatest diversity of beneficials was observed on trees of apples followed by cherries.

Important presence of ants (Figure 3), represented by the common species *Lasius niger*, was observed associating with aphid colonies especially *Myzus cerasi* (on cherries), *Aphis pomi* and *Dysaphis plantaginea* (on apples). Early presence (on the end of Mars) of ants before aphid appearing on cherry trees was recorded, they were observed feeding on the nectar produced by cherry trees. During the period of *M. cerasi* presence on cherry trees, many individuals of ants were simultaneously tended to an aphid colony as a result of the high production of honeydew by *M. cerasi* populations. *Lasius niger* individuals were also strongly tended to *Aphis pomi* and *D. plantaginea* colonies on apple trees. Ant populations began rising in early May at the same time with population dynamic of aphids.

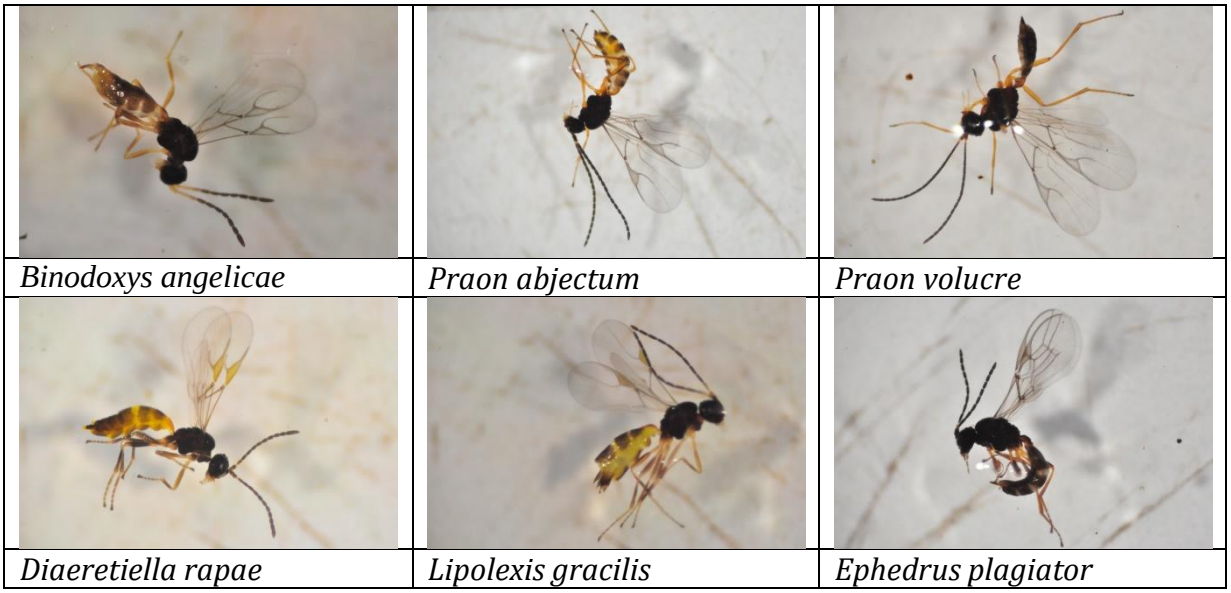

Figure 2. Photos of promising parasitoid candidates for biological aphid control, which are recorded during the present research.

	
Ladybird larvae	Ants on Aphid-infested apple tree
	
Predatory mites	Spiders

Figure 3. Photos of some predatory beneficials, observed in our study, that share the same habitat with aphid parasitoids in fruit orchards.

Current crop protection practices

The tables provided in annex 1 show the different pests and diseases occurring on fruit trees of pears, apples and cherries, in Belgian orchards, at different phenological development stages and the related current crop protection practices. Analyzing these tables will allow us to build a new IPM approach for aphid control based on the releasing of commercially produced parasitoids. This biological control technique requires an optimal positioning of the parasitoid releases, the replacement of incompatible chemical treatments and the identification of other possible bottlenecks.

Concerning fungal disease management, based on several data sources concerning side effects on beneficial arthropods (IOBC, Biobest, Koppert, Viridaxis, pcfruit), none of the currently used fungicides is known to have an unacceptable side effect on parasitoids.

Hence, current fungicidal sprayings seem to be compatible with parasitoid releases. However, it is still uncertain if there might be a deterrent effect of multiple sprayings and the potential exposure of parasitoids to a cocktail of different active ingredients. Therefore, multiple successive calendar based fungicide sprayings should be avoided. One should only spray when really required based on warnings (spore countings, infection risk models (based on climatologically conditions)).

Considering the climatological conditions in northwest Europe, the cold weather conditions in the preflowering period in the different fruit tree crops are often limiting the activity of parasitoids. Hence, parasitoid releases can take place only from the (post-) flowering period onwards. For this reason, potential non-selective sprayings (with products having a short period of activity) early in the season targeting early developing pests can be compatible with later releases of parasitoids, provided that the persistence/toxic effect of the early season control sprayings has faded at the moment of parasitoid releases. Control sprayings around and after flowering however can actually disrupt the (built up of) released parasitoids (populations).

Concerning insecticide and acaricide applications, there are some bottlenecks regarding compatibility of current chemical sprayings with the release of parasitoids.

Apple (*Malus domestica*)

For the preflowering/flowering period, except of aphids three arthropod pests can generate problems for apple trees, they include spider mites, apple blossom weevil and caterpillars of winter and leafroller moths. Some products like thiacloprid and pyrethroids might harm parasitoids if the residue is still present during parasitoid releases.

> Potential solutions: Mineral oil against spider mites early in the season (these early season applications will not have any detrimental effect anymore after flowering when parasitoids are released. Later on, for mite control, in the preflowering period the more selective hexythiazox can be used. For caterpillar control the selective insect growth regulators (e.g. tebufenozide, methoxyfenozide) and *Bacillus thurigiensis* (Bt) products can be used. For control of apple blossom weevil there is no chemical compatible solution. However, if thiacloprid is used before flowering, and only several weeks after thiacloprid treatment parasitoids are

released the detrimental effect should be minimal due to the principle of selectivity in time (Bangels et al. 2009; Goossens et al. 2011).

For post-flowering and fruit set periods, multiple serious pests are attacking apple trees and the use of incompatible chemicals should be avoided.

Potential solutions: Using of mating disruption products against moths and BT products when necessary. Use of selective products against spider mites like hexythiazox. For the woolly apple aphid (*Erisoma lanigerum*) on sensitive cultivars, the parasitoid *Aphelinus mali*, is often efficient against this aphid. Sprayings with chemicals should be avoided during the parasitoid adult flights (Belien et al. 2011; Goossens et al. 2011). In line with this, also for released parasitoids chemical sprayings should be avoided during the adult flights, but correction sprays might be still possible during the endoparasitic stage.

Pear (*Pyrus communis*)

Several aphids can generate economic damages for pear trees. However, their damages are limited following the actual necessity to use insecticides in order to control the very frequent pest on pear trees, the pear psylla *Cacopsylla pyri*. Since many insecticides used against *C. pyri* are not compatible with the use of Hymenopteran parasitoids, it is for now impossible to implement any biological control of aphids with parasitoids in pear orchards. Research are actually running to develop a natural control against the pear psylla, on which can allow us in the future to develop natural control program against pear aphids.

Cherry (*Prunus avium*)

For the preflowering/flowering period, except of aphids two arthropod pests can generally generate problems for cherry trees: spider mites, and caterpillars of winter and leafroller moths. Some products like thiacloprid might harm parasitoids if the residue is still present during parasitoid releases.

Potential solutions: Use mating disruption products or insect growth regulators/BT products when necessary, against moths, and use selective products

against spider mites like hexythiazox. Mineral oil against spider mites can be also used early in the season.

For the post-flowering and fruit set periods, except of aphids only leafroller moths generally can cause problems for cherry trees. Potential solution: use mating disruption products or insect growth regulators/BT products when necessary, against moths.

If aphids are locally not sufficiently controlled, localized applications of pirimicarb could be used. This carbamate product has a short persistence time which allows reintroducing parasitoids one week after the treatment.

During the fruit ripening process, big aphid problems are rare. Anyway, arrival of cherry flies (*Rhagoletis* sp) and/or fruit flies (*Drosophila suzukii*) currently often necessitates the repetitive use of different chemicals (thiacloprid, acetamiprid, spinosad and dimethoate) which are not compatible with the use of parasitic wasps. Only when biological/IPM solutions are developed and become available for control this severe pest flies in practice, one can consider usage of parasitoid releases at this stage.

Discussion

This study provides baseline knowledge on the fauna of aphids and beneficials in fruit orchards involving the associated flora in the eastern area of Belgium, which can be an important database to develop an efficient parasitoid releasing strategy against pest aphids.

The Aphidiine parasitoids were collected from their host aphids on cropping and non-cropping plants; whereas the predatory beneficials were observed on both aphid colonies and fruit trees. *Toxares deltiger* is a relatively rare aphid parasitoid in European orchards, for the first time we detected this parasitoid attacking *Dysaphis plantaginea* on apple trees. According to van Achterberg (2004), *T. deltiger* is rarely collected in Europe and this species has been recorded in England (Powell 1982) and Poland (Pankanin-Franczyk 1998) emerging from cereal aphid, *Metopolophium dirhodum* Walker. Based on our observation, there were two important periods (May and October) of parasitoid presence on the non-cropping plants. The first period is necessary for the biological aphid control in fruit orchards for the current growing season, and the second period is necessary for control during the next growing season. Both periods are also of high

importance for the beneficial fauna in the nature facing the challenges resulting from the non-selective chemicals used against pests on cropping plants.

Many of the collected aphid parasitoids can be categorized as narrowly oligophagous species (e.g., *A. mali*, *A. absinthii*, *A. phalangomyzi*, *A. rosae*, *A. eadyi*, *B. acalaphae*, *B. heraclei, E. nacheri, L. cardui, P. yomenae, T. deltiger, T. falcatus, T. pallidus*) and broadly oligophagous species (*A. colemani, A. ervi, A. matricariae, D. rapae, E. persicae, L. gracilis, L. confusus, L. fabarum, P. volucre*) (Kavallieratos et al. 2004; Starý 2006). On the other side, few predators can be categorised as narrowly oligophagous species, e.g. predatory hoverflies that are specialist predators on aphids. Following the important presence of parasitoids on the associated flora, more studies are needed on the associations of aphids with especially *Capsella bursa-pastoris*, *Chenopodium album*, *Epilobium hirsutum*, *Rumex obtusifolius*, *Sambucus nigra*, *Sonchus asper* and *Senecio vulagris* for the potential use in supporting parasitoid releasing against aphids. Using these candidates should be effectuated at the same time with landscape management in order to manipulate predatory arthropods and decrease their negative actions against parasitoids. Aphid parasitoid-predator interactions are always asymmetric, in favor of the predators. Implicitly, a specialist parasitoid is not adapted to attack non-host insects, and is thus disadvantaged during confrontations with generalist predators.

High risk of predation on parasitic adults by spiders can be also expected, thus before any parasitoid releasing, an application of water spraying could help temporary in suppressing spider nets and decrease the risk level of these nets on parasitic wasps. A study conducted by Völkl and Kraus (1996) indicated that mortality among parasitic wasp adults ranked between 11 to more than 50 %. A quantitative field study of the impact of predators on foraging parasitoid females was conducted by Heimpel et al. (1997), who observed that several predators including spiders and ants have the capacity to capture two different species of parasitoids. He found that the intraguild predation on parasitoids by these predators significantly reduced parasitoid fitness during specific seasonal periods of high predation risk.

Our observations on the seasonal occurrence of parasitoid-aphid-plant associations also indicate to some extent the phenology and a possibility of parasitoid populations to alternate between the individual host species (and ecosystems) during the season. An analysis of the associations (table 1 and 2) indicated several parasitoid species as the

key-stone species which should be considered as promising candidates for preventive application against aphids on fruit tree crops. These species are at least as follows: *Binodoxys angelicae*, *Ephedrus plagiator*, *Aphidius matricariae* Haliday, *Praon volucre* Haliday and *Praon abjectum* Haliday, some of them already produced by Viridaxis.

Regarding crop protection practices, if we want to apply an IPM strategy for aphid control using releases of parasitic wasps in fruit orchards, the most appropriate period is between the preflowering stage and the beginning of the ripening process. Investigations, developments and practical applications of environment-friendly biological control methods against other pests on fruit trees are highly recommended to decrease the unwanted side effects on the beneficial fauna and in the same time increase the efficiency level of parasitoids for the long-term management of aphids. Further behavioural studies are highly recommended to achieve the optimal way about how we can combine new biological control agents with the other beneficials and arthropods already present in the target orchard to increase their overall efficacy against aphids.

In conclusion, parasitized aphids, mummified aphids, and adult aphid parasitoids may interact with a large guild of natural enemies. Whether natural enemies with different modes of action and host/prey specificity can be integrated in biological control programmes, depends on a variety of abiotic and biotic factors. Understanding the complex relationships between intraguild natural enemies of aphids and the efficient ant management is a crucial step towards implementing both curative and preventive biological control strategies in open field conditions.

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Table 1. A list of aphid – beneficial – ant interactions observed on fruit trees in the study area (- : nothing, + : low , ++ : medium, +++ : high).

Host Plants / Aphids	**Ant density**	**Parasitoid wasps**	**Predators**
Malus domestica			
Eriosoma lanigerum	+	*Aphelinus mali*	**Coccinellidae** *Coccinella septempunctata* *Harmonia axyridis* *Propylea quatuordecimpunctata* **Syrphidae** *Episyrphus balteatus* *Syrphus* sp. *Scaeva pyrastri* *Eupeodes* sp. *Platycheirus* sp. **Anthocoridae** *Anthocoris* sp. *Orius* sp. **Miridae** *Daerocoris* sp. **Chrysopidae** *Chrysoperla* sp. **Forficulidae** *Forficula auricularia* **Cecidomyiidae** *Aphidoletes aphidimyza* **Spiders** **Mites**
Dysaphis plantaginea	+++	*Ephedrus persicae*	
		Ephedrus plagiator	
		Binodoxys angelicae	
		Praon abjectum,	
		Toxares deltiger	
		Lipolexis gracilis	
		Diaeretiella rapae	
		Aphidius ervi	
		Aphidius urticae	
Aphis pomi	+++	*Ephedrus persicae*	
		Ephedrus plagiator	
		Praon volucre	
		Lysiphlebus fabarum	
		Binodoxys angelicae	
Aphis spiraecola	+++	-	
Macrosiphum euphorbiae	-	-	
Dysaphis devecta	++	-	
Rhopalosiphum insertum	-	*Ephedrus plagiator*	
Prunus avium			
Myzus cerasi	+++	*Ephedrus persicae*	**Coccinellidae** *Coccinella septempunctata* *Harmonia axyridis* *Propylea quatuordecimpunctata* **Syrphidae** *Episyrphus balteatus* *Scaeva pyrastri* **Anthocoridae** *Orius* sp. **Chrysopidae** *Chrysoperla* sp. **Forficulidae** *Forficula auricularia* **Cecidomyiidae** *Aphidoletes aphidimyza* **Spiders** **Mites**
		Aphidius matricariae	
		Binodoxys angelicae	
		Ephedrus plagiator	
Brachycaudus helichrysi	+	-	
Myzus lythri	-	-	

(Table 1 continued)

Pyrus communis			
Macrosiphum euphorbiae	-	*Praon volucre*	**Coccinellidae** *Coccinella septempunctata* *Harmonia axyridis* *Propylea quatuordecimpunctata* **Syrphidae** *Episyrphus balteatus* **Anthocoridae** *Orius* sp. **Chrysopidae** *Chrysoperla* sp. **Forficulidae** *Forficula auricularia* **Cecidomyiidae** *Aphidoletes aphidimyza* **Spiders** **Mites**
Macrosiphum rosae	-		
Aphis spiraecola	+++		
Aphis pomi	+++		
Melanahpis pyraria	+		
Rhopalosiphum insertum	-	*Ephedrus persicae*	
Rhopalosiphum nymphaeae	-		
Myzus varians	++		
Myzus persicae	+	-	
Prunus domestica & insititia			
Aphis fabae	++	*Binodoxys angelicae*	**Coccinellidae** *Coccinella septempunctata* *Harmonia axyridis* **Syrphidae** *Episyrphus balteatus* *Syrphus* sp. *Sphaerophoria scripta* **Anthocoridae** *Orius* sp. **Chrysopidae** *Chrysoperla* sp. **Forficulidae** *Forficula auricularia* **Cecidomyiidae** *Aphidoletes aphidimyza* **Spiders**
		Binodoxys sp.	
		Praon abjectum	
		Aphelinus sp.	
		Ephedrus plagiator	
		Ephedrus persicae	
Brachycaudus helichrysi	++	*Ephedrus persicae*	
Hyalopterus pruni	+	*Praon abjectum*	
		Ephedrus persicae	
Prunus insititia			
Aphis fabae	++	*Binodoxys angelicae*	
		Praon abjectum	
		Ephedrus plagiator	
Brachycaudus helichrysi	++	*Ephedrus persicae*	
Hyalopterus pruni	+	*Ephedrus persicae*	
Prunus persicae			
Myzus varians	++	-	**Coccinellidae** *Coccinella septempunctata* **Syrphidae** *Episyrphus balteatus* *Syrphus* sp. **Anthocoridae** *Orius* sp. **Cecidomyiidae** *Aphidoletes aphidimyza* **Spiders**
Myzus persicae	+	-	
Brachycaudus persicae	+	-	

Table 2. A list of aphid – plant and aphid – parasitoid – plant associations in the study area (- : no parasitoid emergence or no parasitism was observed on aphids).

Aphids	Parasitoids	Plants
Acyrthosiphon malvae	-	*Geranium pyrenaicum*
Acyrthosiphon malvae ssp rogersii	*Aphidius ervi*	*Fragaria ananassa*
	Aphidius urticae	*Fragaria ananassa*
	Praon volucre	*Fragaria ananassa*
Acyrthosiphon pisum	*Aphidius eadyi*	*Trifolium repens*
	Aphidius ervi	*Vicia hirsuta*
		Medicago lupulina
		Trifolium repens
	Aphidius urticae	*Trifolium pratense*
	Praon volucre	*Medicago sativa*
Amphoraphora idaei	*Aphidius urticae*	*Rubus idaeus*
Amphoraphora rubi	-	*Rubus fruticosus*
Aphidura bozhkoae	-	*Prunus spinosa*
Aphis (senecionis)	*Lysiphlebus fabarum*	*Senecio vulgaris*
Aphis carduella	-	*Chenopodium album*
Aphis craccivora	*Binodoxys angelicae*	*Capsella bursa-pastoris*
	Diaeretiella rapae	*Capsella bursa-pastoris*
	Ephedrus plagiator	*Capsella bursa-pastoris*
	Liplolexis gracilis	*Capsella bursa-pastoris*
Aphis epilobiaria	*Binodoxys angelicae*	*Epilobium hirsutum*
	Praon abjectum	*Epilobium hirsutum*
Aphis epilobii	*Binodoxys angelicae*	*Epilobium hirsutum*
	Praon abjectum	*Epilobium hirsutum*
Aphis fabae	*Aphelinus* sp.	*Prunus domestica*
		Cirsium arvense
	Aphidius urticae	*Arctium lappa*
	Aphidius colemani	*Myosotis arvensis*
	Binodoxys angelicae	*Ribes rubrum*
		Prunus domestica
		Prunus insititia
		Arctium lappa
		Capsella bursa-pastoris
		Cirsium arvense
		Galium aparine
		Rumex obtusifolius
		Tanacetum parthenium
	Binodoxys sp.	*Prunus domestica*
	Diaeretiella rapae	*Chenopodium album*
		Capsella bursa-pastoris
	Ephedrus persicae	*Prunus domestica*
	Ephedrus plagiator	*Prunus domestica*
		Prunus insititia
		Capsella bursa-pastoris
		Chenopodium album
		Rumex obtusifolius

(Table 2 continued)

		Euonymus europaeus
	Liplolexis gracilis	*Capsella bursa-pastoris*
	Lysiphlebus confusus	*Cirsium arvense*
	Lysiphlebus fabarum	*Arctium lappa*
		Beta vulgaris
		Carduus crispus
		Chenopodium album
		Cirsium arvense
		Digitalis purpurea
		Galinosa quadriradiata
		Galium aparine
		Helianthus annus
		Ribes rubrum
		Rumex obtusifolius
		Senecio inaequidens
		Sonchus arvensis
		Sonchus asper
		Tanacetum vulgare
		Tripleurosperum maritimum
		Vicia faba
	Lysiphlebus hirticornis	*Tanacetum vulgare*
	Praon abjectum	*Prunus domestica*
		Prunus insititia
		Sonchus asper
	Praon volucre	*Chenopodium album*
		Cirsium arvense
		Galium aparine
		Tanacetum parthenium
	-	*Senecio vulgaris*
	-	*Lamium purpureum*
	-	*Solanum nigrum*
Aphis farinosa	*Lysiphlebus confusus*	*Salix sachalinensis (udensis)*
Aphis frangulae	*Binodoxys angelicae*	*Capsella bursa-pastoris*
Aphis gossypii	*Binodoxys angelicae*	*Capsella bursa-pastoris*
	Diaeretiella rapae	*Capsella bursa-pastoris*
	Liplolexis gracilis	*Capsella bursa-pastoris*
Aphis grossulariae	*Binodoxys angelicae*	*Epilobium hirsutum*
	Ephedrus plagiator	*Epilobium hirsutum*
	Lysiphlebus confusus	*Ribes rubrum*
		Rubus fruticosus
	Praon volucre	*Epilobium hirsutum*
Aphis jacobaeae	*Aphidius ervi*	*Senecio inaequidens*
	Binodoxys angelicae	*Senecio jacobaea*
	Lysiphlebus confusus	*Senecio inaequidens*
	Lysiphlebus fabarum	*Senecio jacobaea*
Aphis nasturtii	*Binodoxys angelicae*	*Capsella bursa-pastoris*
		Epilobium hirsutum

(Table 2 continued)

	Diaeretiella rapae	*Capsella bursa-pastoris*
		Epilobium hirsutum
	Ephedrus plagiator	*Capsella bursa-pastoris*
	Liplolexis gracilis	*Capsella bursa-pastoris*
		Rumex obtusifolius
	Lysiphlebus fabarum	*Rumex obtusifolius*
Aphis oenotherae	*Ephedrus plagiator*	*Epilobium hirsutum*
Aphis origani	*Aphidius colemani*	*Satureja montana*
Aphis polygonata	*Binodoxys angelicae*	*Polygonum aviculare*
	Diaeretiella rapae	*Polygonum aviculare*
	Ephedrus plagiator	*Polygonum aviculare*
	Liplolexis gracilis	*Polygonum aviculare*
Aphis pomi	*Binodoxys angelicae*	*Malus domestica*
		Crataegus monogyna
	Ephedrus persicae	*Malus domestica*
	Ephedrus plagiator	*Malus domestica*
	Lysiphlebus fabarum	*Malus domestica*
	Praon volucre	*Malus domestica*
	-	*Prunus spinosa*
	-	*Pyrus domestica*
Aphis rumicis	*Aphidius uzbekistanicus*	*Rumex obtusifolius*
Aphis sambuci	*Binodoxys angelicae*	*Sambucus nigra*
	Ephedrus plagiator	*Sambucus nigra*
	Lysiphlebus sp.	*Sambucus nigra*
	Praon abjectum	*Sambucus nigra*
Aphis schneideri	*Lysiphlebus confusus*	*Ribes nigrum*
		Ribes rubrum
Aphis spiraecola	-	*Malus domestica*
	-	*Pyrus communis*
Aphis sp.	*Binodoxys acalaphae*	*Epilobium hirsutum*
	Binodoxys angelicae	*Epilobium hirsutum*
	Praon abjectum	*Epilobium hirsutum*
	-	*Sonchus asper*
	-	*Rumex obtusifolius*
	-	*Tanacetum vulgare*
Aphis urticata	*Lysiphlebus fabarum*	*Urtica dioica*
Aulacorthum solani	*Aphidius ervi*	*Origanum vulgare*
		Plantago lanceolata
		Senecio vulgaris
		Rubus fruticosus
	Aphidius matricariae	*Bellis perennis*
	Aphidius urticae	*Fuchsia magellanica*
	Praon volucre	*Fuchsia magellanica*
		Solanum nigrum
	-	*Artemisia vulgaris*
	-	*Geranium pyrenaicum*
	-	*Mysotis arvensis*

(Table 2 continued)

	-	*Rumex obtusifolius*
	-	*Silene latifolia*
	-	*Chenopodium album*
	-	*Lotus corniculatus*
Brachycaudus sp.	-	*Tripleurosperum maritimum*
Brachycaudus lychindis	*Aphidius ervi*	*Silene latifolia*
	Lysiphlebus fabarum	*Silene latifolia*
Brachycaudus cardui	*Aphidius colemani*	*Myosotis arvensis*
		Senecio vulgaris
	Aphidius ervi	*Senecio vulgaris*
	Aphidius matricariae	*Senecio vulgaris*
		Tripleurosperum maritimum
	Aphidius smithi	*Senecio vulgaris*
	Aphidius sp.	*Senecio vulgaris*
	Binodoxys angelicae	*Cirsium arvense*
		Tanacetum parthenium
		Senecio vulgaris
	Ephedrus persicae	*Senecio vulgaris*
	Ephedrus plagiator	*Leucanthemum vulgare*
		Senecio vulgaris
		Tripleurosperum maritimum
	Liplolexis gracilis	*Senecio vulgaris*
	Lysiphlebus brachycaudi	*Tripleurosperum maritimum*
		Senecio vulgaris
	Lysiphlebus cardui	*Cirsium arvense*
	Lysiphlebus fabarum	*Achillea millefolium*
		Anthemis tinctoria
		Carduus crispus
		Cirsium arvense
		Cirsium vulgare
		Helianthus annus
		Senecio vulgaris
		Tanacetum vulgare
	Praon volucre	*Tanacetum parthenium*
	-	*Artemisia vulgaris*
	-	*Senecio jacobaeae*
	-	*Bellis perennis*
	-	*Galinosa quadriradiata*
Brachycaudus helichrysi	*Aphelinus* sp.	*Prunus spinosa*
	Aphidius colemani	*Prunus spinosa*
		Myosotis arvensis
	Aphidius ervi	*Senecio inaequidens*
	Ephedrus persicae	*Prunus domestica*
		Prunus insititia
		Prunus spinosa
	Ephedrus plagiator	*Prunus spinosa*
	Lysiphlebus confusus	*Prunus spinosa*

(Table 2 continued)

		Senecio inaequidens
	Lysiphlebus fabarum	*Achillea millefolium*
		Carduus crispus
		Cirsium arvense
		Helianthus annus
		Tanacetum vulgare
		Tripleurosperum maritimum
	Lysiphlebus hirticornis	*Tanacetum vulgare*
	-	*Prunus avium*
	-	*Tanacetum parthenium*
Capitophorus elaegni	-	*Cirsium arvense*
Capitophorus horni	*Aphidius matricariae*	*Cirsium arvense*
	-	*Cirsium arvense*
Capitophorus sp.	-	*Pulicaria dysenterica*
Cavariella eagopodii	*Binodoxys heraclei*	*Heracleum sphondylium*
Cavariella pastinacae	*Lysiphlebus confusus*	*Salix sachalinensis (udensis)*
	-	*Heracleum sphondylium*
Cryptomyzus alboapicalis	*Aphidius colemani*	*Lamim album*
	Aphidius ervi	*Lamim album*
Cryptomyzus galeopsidis	-	*Ribes nigrum*
Cryptomyzus maudamanti	*Aphidius ribis*	*Ribes rubrum*
Cryptomyzus ribis	*Aphidius ribis*	*Ribes rubrum*
	-	*Lamium album*
Drepanosiphum platanoides	*Falciconus pseudoplatanii*	*Acer pseudoplatanus*
Dysaphis sp.	-	*Heracleum sphondylium*
Dysaphis devecta	-	*Malus domestica*
Dysaphis plantaginea	*Aphidius ervi*	*Malus domestica*
		Plantago lanceolata
	Aphidius urticae	*Malus domestica*
	Binodoxys angelicae	*Malus domestica*
	Diaeretiella rapae	*Malus domestica*
	Ephedrus persicae	*Malus domestica*
	Ephedrus plagiator	*Malus domestica*
	Liplolexis gracilis	*Malus domestica*
	Praon abjectum	*Malus domestica*
	Toxares deltiger	*Malus domestica*
Dysaphis radicola	-	*Rumex obtusifolius*
Eriosoma lanigerum	*Aphelinus mali*	*Malus domestica*
Hayhurstia atriplicis	*Aphelinus sp.*	*Chenopodium album*
	Diaeretiella rapae	*Chenopodium album*
	Ephedrus nacheri	*Chenopodium album*
	Lysiphlebus fabarum	*Chenopodium album*
Hyalopterus pruni	*Ephedrus persicae*	*Prunus domestica*
		Prunus insititia
		Prunus spinosa
	Ephedrus plagiator	*Prunus spinosa*
		Phalaris arundinacea

(Table 2 continued)

		Phragmites australis
	Lysiphlebus confusus	*Prunus spinosa*
	Praon abjectum	*Prunus domestica*
		Prunus spinosa
		Phalaris arundinacea
	Praon volucre	*Prunus spinosa*
		Phalaris arundinacea
		Phragmites australis
Hyperomyzus lactucae	*Aphidius funebris*	*Sonchus oleraceus*
	Aphidius sonchi	*Sonchus arvensis*
		Sonchus asper
	Praon abjectum	*Sonchus arvensis*
		Sonchus asper
	Aphidius colemani	*Sonchus asper*
	Aphidius sp.	*Sonchus asper*
Hyperomyzus pallidus	-	*Sonchus asper*
Lipaphis erysimi	*Diaeretiella rapae*	*Capsella bursa-pastoris*
Lipaphis erysimi	*Ephedrus plagiator*	*Capsella bursa-pastoris*
Macrosiphoniella artemisia	*Aphidius absinthii*	*Artemisia vulgaris*
Macrosiphoniella millefolii	*Aphidius ervi*	*Tanacetum vulgare*
	Aphidius urticae	*Tanacetum vulgare*
	-	*Achillea millefolum*
Macrosiphoniella oblonga	*Aphidius absinthii*	*Artemisia vulgaris*
	Aphidius phalangomyzi	*Artemisia vulgaris*
	-	*Artemisia vulgaris*
Macrosiphum euphorbiae	*Aphidius ervi*	*Bellis perennis*
		Chenopodium album
		Trifolium repens
		Eupatrium cannabinum
	Aphidius matricariae	*Bellis perennis*
	Ephedrus plagiator	*Capsella bursa-pastoris*
	Praon gallicum	*Senecio vulgaris*
	Praon volucre	*Chenopodium album*
		Epilobium hirsutum
		Senecio vulgaris
		Pyrus communis
		Vaccinium corymbosum
	-	*Sonchus asper*
	-	*Malus domestica*
	-	*Cirsium arvense*
	-	*Euphorbia helioscopia*
	-	*Plantago lanceolata*
	-	*Solanum nigrum*
	-	*Stellaria media*
Macrosiphum rosae	*Aphidius rosae*	*Rosa canina*
		Rosa sp.
	Ephedrus plagiator	*Rosa canina*

(Table 2 continued)

		Rosa sp.
	Praon volucre	*Rosa canina*
	-	*Pyrus communis*
Megoura viciae	-	*Medicago lupulina*
Melanaphis pyraria	-	*Pyrus communis*
Metopeurum fuscoviride	*Aphidius tanacetarius*	*Tanacetum vulgare*
	Lysiphlebus fabarum	*Tanacetum vulgare*
	Lysiphlebus hirticornis	*Tanacetum vulgare*
Metopolophium dirhodum	*Aphidius ervi*	*Arrhenatherum elatius*
	Aphidius rhopalosiphi	*Poa annua*
	Praon volucre	*Poa annua*
	-	*Rosa canina*
Microlophium carnosum	*Aphidius ervi*	*Urtica dioica*
	Aphidius funebris	*Urtica dioica*
	Aphidius microlophii	*Urtica urens*
		Urtica dioica
	Aphidius sp.	*Urtica dioica*
	Aphidius urticae	*Urtica dioica*
Myzocallis sp.	-	*Quercus robur*
Myzus ascalonicus	*Aphidius colemani*	*Geranium pyrenaicum*
		Lamim album
	Aphidius ervi	*Cerastium fontanum*
		Lamim album
	Aphidius matricariae	*Cerastium fontanum*
	Aphidius urticae	*Stellaria media*
	Ephedrus plagiator	*Myosotis arvensis*
	Lysiphlebus fabarum	*Papaver sp*
	-	*Rumex obtusifolius*
	-	*Senecio vulgaris*
	-	*Silene latifolia*
Myzus cerasi	*Aphidius matricariae*	*Prunus avium*
	Binodoxys angelicae	*Prunus avium*
	Ephedrus persicae	*Prunus avium*
	Ephedrus plagiator	*Prunus avium*
	-	*Capsella bursa-pastoris*
Myzus certus	*Aphidius colemani*	*Lepidium draba*
Myzus lythri	-	*Prunus avium*
Myzus persicae	*Aphidius matricariae*	*Bellis perennis*
		Capsella bursa-pastoris
		Senecio vulgaris
		Tripleurosperum maritimum
	Aphidius urticae	*Stellaria media*
	Ephedrus persicae	*Senecio vulgaris*
	Ephedrus plagiator	*Capsella bursa-pastoris*
		Senecio vulgaris
		Tripleurosperum maritimum
	Lysiphlebus fabarum	*Papaver* sp.

(Table 2 continued)

	Lysiphlebus fabarum	*Senecio vulgaris*
		Trifolium repens
	-	*Pyrus communis*
	-	*Silene latifolia*
Myzus sp.	-	*Medicago lupulina*
Myzus varinas	-	*Prunus persicae*
	-	*Pyrus communis*
	-	*Nasonovia ribisnigri*
Periphyllus acericola	*Aphidius setiger*	*Acer pseudoplatanus*
	Trioxys falcatus	*Acer pseudoplatanus*
Periphyllus aceris	-	*Acer pseudoplatanus*
Periphyllus californiesis	-	*Acer pseudoplatanus*
Periphyllus hirticornis	*Trioxys falcatus*	*Acer campestre*
Periphyllus testudinaceus	*Aphidius setiger*	*Acer campestre*
Phorodon humuli	*Ephedrus persicae*	*Prunus spinosa*
	Ephedrus plagiator	*Prunus spinosa*
Pterocallis alni	*Trioxys pallidus*	*Alnus glutinosa*
Rhopalosiphonius latysiphon	-	*Stellaria media*
Rhopalosiphum insertum	*Ephedrus persicae*	*Pyrus communis*
	Ephedrus plagiator	*Malus domestica*
Rhopalosiphum nymphaeae	-	*Prunus spinose*
	-	*Pyrus communis*
Rhopalosiphum padi	*Ephedrus plagiator*	*Prunus padus*
		Zea mays
	-	*Poa annua*
	-	*Capsella bursa-pastoris*
	-	*Plantago lanceolata*
Sitobion avenae	*Aphidius avenae*	*Poa annua*
	Aphidius ervi	*Poa annua*
	Aphidius rhopalosiphi	*Poa annua*
	Aphidius uzbekistanicus	*Poa annua*
	Ephedrus plagiator	*Poa annua*
	Praon volucre	*Poa annua*
Sitobion fragariae	-	*Poa annua*
	-	*Rubus fruticosus*
Tuberculatus annulatus	*Praon flavinode*	*Quercus robur*
	Trioxys pallidus	*Quercus robur*
Uroleucon cirsii	*Aphidius funebris*	*Cirsium arvense*
	-	*Cirsium arvense*
Uroleucon aeneum	-	*Carduus crispus*
Uroleucon jaceae	*Aphidius funebris*	*Centaurea jacea*
	-	*Carduus crispus*
	-	*Centaurea jacea*
Uroleucon sonchi	*Aphidius funebris*	*Sonchus asper*
		Sonchus oleraceus
	Aphidius sonchi	*Sonchus asper*
		Sonchus arvensis

(Table 2 continued)

	Praon yomenae	*Sonchus asper*
Uroleucon tanaceti	-	*Tanacetum parthenium*
	-	*Tanacetum vulgare*

Annex 1: Common pests and diseases presence and current crop protection practices in apple, pear and cherry orchards in relation with phenological stages of the crops (aphids and products sprayed targeting aphid control are indicated in red)

Apple orchards

Phenology		Insects / Mites / treatments			Fungus / treatments		
	BBCH-scale	**Target pest**	**Product**	**Active ingredient**	**Name**	**Product**	**Active ingredient**
Winter	00 - Dormancy 51 - Buds elongating	Oystershell scale - *Quadraspidiotus ostreaeformis*	mineral oil	paraffin oil	Canker - *Nectria galligena* (wintering) Scab - *Venturia inaequalis* (wintering)	copper hydroxide	copper hydroxide
						copper oxychloride	copper oxychloride
Preflowering	52 - Swelling 53 - Bud burst	Apple Blossom Weevil - *anthonomus pomorum*	Calypso	thiacloprid	Scab - *Venturia inaequalis*	Syllit	dodine
		Aphids - *Aphidoidea*					
		Spider Mites - *Tetranychidae*	mineral oil	paraffin oil			
	54 - Mouse ear 55 - Green cluster 56 - Green bud (prewhite) 57 - Pink bud 59 - Balloon stage 60 - First flowers open	Plant Bugs - *Lygus, Campylomma*	Calypso	thiacloprid			
		Rosy Apple Aphid - *Dysaphis plantaginea*					
			Teppeki	flonicamid	Powdery Mildew - *Podosphaera leucotricha*		sulphur
		Spider Mites - *Tetranychidae*	Nissorun	hexythiazox			
		Winter Moth - *Operophtera brumata* Leafroller Moths - *Tortricidae*	Steward	indoxacarb	Scab - *Venturia inaequalis* (preventive)	Captan	captan
			Mimic	tebufenozide		Delan	dithianon
			Runner	methoxyfenozide		Ditho	
					Scab - *Venturia inaequalis* (curative)	Captan Chorus	captan cyprodinil
Bloom	61 - Beginning of bloom (10% of flowers open) 65 - Full bloom (50% of flowers open)	Spider Mites - *Tetranychidae (50 - 80%)*	Danitron (not when bees are foraging)	fenpyroximate		Captan Scala	captan pyrimethanil
						Captan Geyser	captan difenoconazole
		Rust Mites - *Eriophyidae*			Powdery Mildew - *Podosphaera leucotricha*	Topaz / Topenco	penconazole
		Leafroller Moths - *Tortricidae* Caterpillars	Runner	methoxyfenozide			
			Mimic	tebufenozide			
			Steward	indoxacarb			

After bloom	67 - Flowers fading (majority of petals fallen) 69 - End of bloom (fruit fall after flowering)	Spider Mites - *Tetranychidae (100%)*			Scab - *Venturia inaequalis* (preventive)	Captan	captan
		Caterpillars					
		Gall Midges - *Dasineura spp.*					
		Wooly Apple Aphid - *Eriosoma lanigerum*	Movento	spirotetramat			
			Pirimor Trend	pirimicarb isodecyl-alcohol ethoxylate			
		Rosy Apple Aphid - *Dysaphis plantaginea*	Calypso	thiacloprid			
			Teppeki	flonicamid	Scab - *Venturia inaequalis* (curative)	Captan Geyser	captan difenoconazole
			Movento	spirotetramat		Delan / Ditho Geyser	dithianon difenoconazole
		Apple Mussel Scale - *Lepidosaphes ulmi*			Powdery Mildew - *Podosphaera leucotricha*	Exact	triadimenol
			Envidor	spirodiclofen	Scab - *Venturia inaequalis* + Powdery Mildew - *Podosphaera leucotricha*	Candit Captan	kresoxim-methyl captan
		Plant Bugs - *Lygus, Campylomma* Sawfly - *Symphyta*	Calypso	thiacloprid		Flint Captan	trifloxystrobin captan
		Codling Moth - *Cydia pomonella*				Candit Delan	kresoxim-methyl dithianon
			Insegar	fenoxycarb		Flint Delan	trifloxystrobin dithianon
		Leafroller Moths - *Tortricidae*				Maccani	pyraclostrobin & dithianon
Fruit set	71 - Fruit size up to 10 mm 72 - Fruit size up to 20 mm 73 - Beginning of fruit fall 73 - End of fruit fall	Codling Moth - *Cydia pomonella* (egg)	Coragen	chlorantraniliprole	Scab - *Venturia inaequalis*	Captan	captan
		Codling Moth - *Cydia pomonella* (larvae)	Runner	methoxyfenozide		Delan	dithianon
			Granulose virus				
		Spider Mites - *Tetranychidae* Rust Mites - *Eriophyidae*				Pomarsol	thiram
		Oystershell scale - *Quadraspidiotus ostreaeformis*					
		Leafroller Moths - *Tortricidae*			Powdery Mildew - *Podosphaera leucotricha*	Nissodium	cyflufenamid
		Wooly Apple Aphid - *Eriosoma lanigerum*	Pirimor Trend	pirimicarb isodecyl-alcohol ethoxylate		Topaz / Topenco	penconazole
						Bellis	pyraclostrobin & boscalid
Summer	81 - Beginning of ripening : 1st appearance of cultivar-specific colour 85 - Advanced ripening: increase in	Codling Moth - *Cydia pomonella*	Affirm (> July 1)	emamectin benzoate	Storage pathogens - *Botrytis cinerea* - *Gloeosporium spp.* - *Penicillium*	Captan	captan
						Pomarsol	thiram
			Coragen	chlorantraniliprole		Bellis	pyraclostrobin & boscalid

	intensity of cultivar-specific colour 87 - Harvest : Fruit ripe for picking 89 - End of harvest : Fruit ripe for optimal consumption		Granulose virus		*spp.* *- Monilia spp.* *- ...*	Switch	cyprodinil & fludioxonil
		Eulia - *Argyrotaenia ljungiana*	*Bacillus thuringensis*	*Bacillus thuringensis*		Bellis	pyraclostrobin & boscalid
						Switch	cyprodinil & fludioxonil
After harvest	93 - Beginning of leaf fall 97 - End of leaf fall				Canker - *Nectria galligena*	Captan	captan
						Topsin M	thiophanate-methyl
						copper hydroxide	copper hydroxide
						copper oxychloride	copper oxychloride

Pear orchards

Phenology		**Insects / Mites / treatments**			**Fungus / treatments**		
	BBCH-scale	**Species**	**Product**	**Active ingredient**	**Name**	**Product**	**Active ingredient**
Winter	00 - Dormancy 51 - Buds elongating	Pear Psylla - *Psylla pyri*	Decis	deltamethrin	Wintering bacterial cankers + *Pseudomonas* + Scab - *Venturia pyrina*	copper hydroxide	copper hydroxide
			Splendid	deltamethrin		copper oxychloride	copper oxychloride
			Patriot	deltamethrin			
			Surround WP	kaolin			
	52 - Swelling 53 - Bud burst	Oystershell scale - *Quadraspidiotus ostreaeformis*	mineral oil	paraffin oil	Scab - *Venturia pyrina*	Syllit	dodine
		Pear Leaf Blister Mite - *Eriophyes pyri*	side effect sulfur	sulphur			
Preflowering	54 - Mouse ear 55 - Green cluster 56 - Green bud (prewhite) 57 - White bud 59 - Balloon stage 60 - First flowers open	Pear Midge - *Contarinia pyrivora*				Captan	captan
		Aphids - *Aphidoidea*	Teppeki	flonicamid			
		Spider Mites - *Tetranychidae*					
		Rust Mites - *Eriophyidae*					
		Winter Moth - *Operophtera brumata*					
		Pear Psylla - *Psylla pyri*	Calypso	thiacloprid			
		Plant Bugs - *Lygus, Campylomma*					
Bloom	61 - Beginning of bloom (10% of flowers open) 65 - Full bloom (50% of flowers open)	Spider Mites - *Tetranychidae*			Scab - *Venturia pyrina* (preventive)	Captan	captan
		Rust Mites - *Eriophyidae*			Scab - *Venturia pyrina* (curative)	Captan Chorus	captan cyprodinil
						Captan Scala	captan pyrimethanil
						Captan Geyser	captan difenoconazole
					Powdery Mildew - *Podosphaera leucotricha* (Doyenné)	Geyser	difenoconazole
		Leafroller Moths - *Tortricidae*	Runner	methoxyfenozide		Flint	trifloxystrobin
			Mimic	tebufenozide		Maccani	pyraclostrobin & dithianon
			Steward	indoxacarb		Nissodium	cyflufenamid

After bloom	67 - Flowers fading (majority of petals fallen) 69 - End of bloom (fruit fall after flowering)	Spider Mites - *Tetranychidae (80%)*	Borneo	etoxazole	Scab - *Venturia pyrina*	Captan	captan
		Plant Bugs - *Lygus, Campylomma*				Pomarsol	thiram
		Forest Bug - *Pentatoma rufipes*			Powdery Mildew - *Podosphaera leucotricha* (Doyenné)	Geyser	difenoconazole
		Gall Midges - *Dasineura spp.*	Movento	spirotetramat		Flint	trifloxystrobin
		Pear Bedstraw Aphid - *Dysaphis pyri*				Maccani	pyraclostrobin & dithianon
		Apple Mussel Scale - *Lepidosaphes ulmi*				Nissodium	cyflufenamid
			Envidor	spirodiclofen	Brown Spot of Pear - *Stemphylium vesicarium*	Bellis	pyraclostrobin & boscalid
		Caterpillars				Switch	cyprodinil & fludioxonil
		Leafroller Moths - *Tortricidae*	Insegar	fenoxycarb		Flint Captan	trifloxystrobin captan
		Codling Moth - *Cydia pomonella*	Insegar	fenoxycarb		Flint Pomarsol	trifloxystrobin thiram
					Dead buds	Aliette	fosethyl-aluminium
		Pear Psylla - *Psylla pyri*	Envidor	spirodiclofen	Pear Rust - *Gymnosporangium sabinae*	Flint	trifloxystrobin
			Vertimec	abamectin		side effect Geyser	difenoconazole
			Movento	spirotetramat		Candit	kresoxim-methyl
Fruit set	71 - Fruit size up to 10 mm 72 - Fruit size up to 20 mm 73 - Beginning of fruit fall 73 - End of fruit fall	Codling Moth - *Cydia pomonella* (egg)	Coragen	chlorantraniliprole	Scab - *Venturia pyrina*	Captan	captan
		Codling Moth - *Cydia pomonella* (larvae)	Runner	methoxyfenozide			
			Granulose virus				
		Spider Mites - *Tetranychidae* Rust Mites - *Eriophyidae*	Sanmite	pyridaben		Pomarsol	thiram
		Oystershell scale - *Quadraspidiotus ostreaeformis*	Envidor	spirodiclofen	Brown Spot of Pear - *Stemphylium vesicarium*	Bellis	pyraclostrobin & boscalid
						Switch	cyprodinil & fludioxonil
			Movento	spirotetramat		Flint Captan	trifloxystrobin captan
		Leafroller Moths - *Tortricidae*				Flint Pomarsol	trifloxystrobin thiram
Summer	81 - Beginning of ripening : 1st appearance of cultivar-specific colour 85 - Advanced ripening: increase in intensity of cultivar-specific colour 87 - Harvest : Fruit ripe for picking 89 - End of harvest : Fruit ripe for optimal consumption	Pear Psylla - *Psylla pyri*	Atilla	potassium bicarbonate	Storage pathogens - *Botrytis cinerea* - *Gloeosporium spp.* - *Penicillium spp.* - *Monilia spp.* - ...	Captan	captan
						Pomarsol	thiram
		Codling Moth - *Cydia pomonella*	Affirm	emamectin benzoate		Captan	captan
			Coragen	chlorantraniliprole		Bellis	pyraclostrobin & boscalid
			Granulose virus			Switch	cyprodinil & fludioxonil

		Eulia - *Argyrotaenia ljungiana*	*Bacillus thuringensis*	*Bacillus thuringensis*		Bellis	pyraclostrobin & boscalid
After harvest	93 - Beginning of leaf fall 97 - End of leaf fall	Pear Blossom Weevil - *Anthonomus pyri*	Calypso	thiacloprid	Canker - *Nectria galligena*	Captan	captan
		Pear Leaf Blister Mite - *Eriophyes pyri*	side effect sulfur	sulphur		Topsin M	thiophanate-methyl
		Pear Psylla - *Psylla pyri*	Actara	thiamethoxam		copper hydroxide	copper hydroxide
						copper oxychloride	copper oxychloride

Notes for pear and apple orchards : **Following acaracide families are used max 1 x / year**

Apollo – Nissuron – Borneo – Naja – Sanmite – Masaï – Envidor

Cherry orchards

Phenology			**Insects / Mites / treatments**			**Fungus / treatments**		
	BBCH-scale	**BBCH date 2015 early cultivars**	**Species**	**Product**	**Active ingredient**	**Name**	**Product**	**Active ingredient**
Winter	00 - Dormancy 01 - Beginning of bud swelling (leaf buds) 03 - End of leaf bud swelling 10 - First leaves separating 31 - Beginning of shoot growth	01 - 15 March				Bacterial canker - *Pseudomonas syringae pv morsprunorum* *Monilia laxa* *Monilia fructigena*	copper hydroxide (40 %)	copper hydroxide
							copper oxychloride (50 %)	copper oxychloride
Preflowering	53 - Bud burst 55 - Green cluster 56 - Flower pedicel elongating; sepals closed 57 - Sepals open (petal tips visible) 59 - Most flowers with petals forming a hollow ball 60 - First flowers open	53 - 7 April 57 - 11 April	European Red Mite - *Panonychus ulmi* (eggs)	Apollo	clofentezin			
			Aphids - *Aphidoidea* Winter Moth - *Operophtera brumata* Leafroller Moths - *Tortricidae*	Karate Zeon	lambda-cyhalothrin			
				Okapi	pirimicarb lambda-cyhalothrin			
				Ninja	lambda-cyhalothrin			
Bloom	61 - Beginning of bloom (10% of flowers open) 65 - Full bloom (50% of flowers open)	61 - 17 April 65 - 20 April				Blossom and twig dieback - *Pseudomonas syringae* pv *morsprunorum*	Horizon EW	tebuconazole
							Teldor	fenhexamid
							Thiram	thiram
							Captan	captan
After bloom	67 - Flowers fading (majority of petals fallen) 69 - End of bloom (fruit fall after flowering)					Blossom and twig dieback - *Pseudomonas syringae pv morsprunorum* *Alternaria alternata*	Rovral SC	iprodione
							Rovral WG	iprodione
		67 - 25 April 69 - 3 May					Signum	pyraclostrobin boscalid
			Leafroller Moths - Tortricidae Caterpillars	Steward	indoxacarb		Switch	cyprodinil fludioxonil

Fruit set	71 - Ovary growing (fruit fall after flowering) 73 - Second fruit fall 75 - Fruit about half final size 77 - Fruit about 70% of final size 79 - Fruit about 90% of final size	71 - 5 May 73 - 14 May	Aphids - *Aphidoidea* (mainly *Myzus cerasi*) *Winter Moth - Operophtera brumata* *Leafroller Moths - Tortricidae*	Pirimor	pirimicarb	Cherry Scab - *Fusicladium cerasi*	Flint	trifloxystrobin
			Aphids - *Aphidoidea* *Anthonomus rectirostris*	Calypso	thiacloprid	Shot Hole Disease - *Stigmina carpophila* - *Pseudomonas syringae* pv *morsprunorum* - *Clasteropsporium carpophilum*	sulphur	sulphur
						Cherry Leaf Spot - *Blumeriella jaapii*	Syllit 400 SC	dodine
							Delan	dithianon
Summer	81 - Beginning of fruit colouring 85 - Colouring advanced 87 - Fruit ripe for picking	81 - 11 June 85 - 20 June	Cherry Fruit Fly - *Rhagoletis cerasi*	dimethoate products	dimethoate	Botrytis Rot - *Botrytis cinerea*	Captan (80%)	captan
				Movento	spirotetramat		Signum	pyraclostrobin boscalid
				Gazelle	acetamiprid		Horizon EW	tebuconazole
				Calypso	thiacloprid		Switch	cyprodinil fludioxonil
							Teldor	fenhexamid
After harvest	93 - Beginning of leaf fall 97 - End of leaf fall		Cherry Fruit Fly - *Rhagoletis cerasi*	dimethoate products	dimethoate	Cherry Leaf Spot - *Blumeriella jaapii*	Syllit 400 SC	dodine
			Spotted Wing Drosophila - *Drosophila suzukii*				Ditho	dithianon
						Bacterial canker - *Pseudomonas syringae* pv *morsprunorum* *Monilia laxa* *Monilia fructigena*	copper hydroxide (40 %)	copper hydroxide
							copper oxychloride (50 %)	copper oxychloride