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Cacopsylla pyri behaviour on new pear selections for host resistance programs

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Abstract

The resistance to *Cacopsylla pyri* (L.) (Rhynchota Psyllidae) of different pear genotypes using phenotypical screening was evaluated on 33 genotypes from 2003 to 2005. Antixenosis, which arises from the settling of the adults and their reduced oviposition rate, and nymphal antibiosis were recorded using free choice tests. The transfer of resistance to *C. pyri* in interspecies crosses between the European pear species *Pyrus communis* L. and Asian pear species, such as *P. ussuriensis* Maximowicz and *P. pyrifolia* Nakai, to part of the progeny was possible.

Key words: *Cacopsylla pyri*, pear breeding, host plant resistance, phenotypical screening.

Introduction

The major objective of many pear breeding programs is to obtain pear cultivars tolerant or resistant to primary pests and diseases, such as *Cacopsylla pyri* (L.) (Rhynchota Psyllidae), *Erwinia amylovora* (Burrill) Winslow *et al*., *Venturia pirina* Aderhold (Bellini and Nin, 2000).

In Italy and Europe, all commercial pear cultivars are strongly susceptible to the pear psylla *C. pyri*. Both young and old nymphs damage pear in several ways: honeydew excreted by nymphs falls onto leaves and fruits and may kill leaf tissue and russet the fruit. Honeydew acts as a growth medium for black sooty mould fungi, whose and the presence of these fungi on the fruits reduces their market value. In addition, loss of crop and tree vigour, and sometimes loss of trees, can occur due to pear decline disease caused by a phytoplasma. *C. pyri* is considered the major vector of pear decline disease.

The genus *Pyrus* L. include more than 30 species, but only three are actually cultivated for their fruit quality traits, while the others are mainly used as rootstocks (Westigard *et al*., 1970). *P. calleryana* Decne and *P. fauriei* (Westwood) may be used as sources of resistance to *C. pyri* (Westigard *et al*., 1970; Quamme, 1984), but their fruit quality is very poor. On the contrary, *P. ussuriensis* Maximowicz is resistant to *C. pyri,* and its fruit quality is very interesting. When *P. ussuriensis* was crossed with *P. communis* L., 60% of the seedlings were resistant without excessively affecting the qualitative properties of the fruits (Harris and Lamb, 1973; Harris, 1973; Bell and Stuart, 1990).

Pear cultivars resistant to *C. pyri* would offer an alternative to chemical control. The genetic control of resistance to *C. pyri* seems to be a polygenic trait (Bellini and Nin, 2000).

The first pear breeding program, in which a genotype resistant to *C. pyri* was obtained, was carried out in North America from 1920 on (USA and Canada). The resistant parents used in the breeding program had a *P. ussuriensis* genotype, called Illinois 65 (Ill 65) (Westigard *et al*., 1970; Harris, 1973). This genotype was crossed with some *P. communis* cultivars, such as Bartlett and Seckel, in order to obtain hybrids with improved fruit quality. Some of these hybrid seedlings, called selection NY 10255 and NY 10257 were backcrossed with Bartlett and Flemish Beauty. In this way, breeders obtained other selection, such as NY 10352, NY 10353, and NY 10355, actually used as source of resistance to *C. pyri*.

Also in Europe, many breeding programs are being carried out to obtain *C. pyri* resistant genotypes. In Italy, three Institution are working on *C. pyri* resistance: DCA (Dipartimento di Colture Arboree - University of Bologna), DOFI (Dipartimento di Ortoflorofrutticoltura - University of Florence) and the ISF-FO (Istituto Sperimentale per la Frutticoltura di Roma, sezione di Forlì). These research facilities are evaluating many selections obtained by back-crosses of the NY series (Baldassari *et al*., 1996; Rivalta and Dradi, 1998). In France, Robert *et al*. (1999, 2004) developed an early screening method for *C. pyri* resistance evaluation based on phenotypic traits. In Romania, at the Fruit Research Institute Pitesti-Maracineni, Braniste *et al*. (1994) bred *P. communis* with *P. pyrifolia* Nakai and *P. ussuriensis*.

Within *P. communis* there are several old varieties in France (Robert and Raimbault, 2005), eastern Europe (Bell and Stuart, 1990) and Italy that are fairly resistant to psylla, such as 'Spina Carpi'. However, even though this variety is widely used in crosses, it does not transfer the resistance to its progeny (Rivalta and Dradi, 1998).

Recently, in the USA, a transgenic plant of Bartlett (= 'Williams') resistant to *C. pyri* was obtained by inserting the gene *D5C1*, active against both *E. amylovora* and *C. pyricola* (Foerster) (Puterka *et al*., 2002).

P. ussuriensis is the most interesting species because, when crossbred with *P. communis*, it transfers its resistance to psylla to 60% of the progeny.

Previous studies on pear resistance to *C. pyri* and *C.*

pyricola report cases of both non-preference or ovipositional antixenosis and nymphal antibiosis (e.g. Harris, 1973). The real mechanisms regulating these traits of resistant plants are poorly known both physiologically and genetically.

The volatile substances released by the leaves of both resistant and susceptible varieties do not substantially differ, and may therefore not be essential for the major attraction or repulsion of psylla adults (Miller *et al.* 1989). However, this aspect has not yet been investigated with bioassays on pear psylla. Also the pubescence of the leaves is not the cause of the resistance (Bell and Stuart, 1990).

In pear, the cuticle or cuticular membrane consists of a component, called *cutine*, an insoluble polyesther with C_{16}- and C_{18}- *hydroxy* and *hydroxyepoxy* fatty acids as primary monomeres. The resistance of the genotypes is not directly proportional to the thickness of the cuticle: for example, the resistant genotype NY 10355 has a lower cutine content than the susceptible variety 'Williams' (Gérard *et al.*, 1993).

In addition to ovipositional antixenosis, the resistant genotypes show also nymphal antibiosis: less honeydew is produced, nymphal development lasts longer, and nymphal mortality is high (Butt *et al.*, 1988, 1989). Bell (1984) assumed that nymphal mortality could be caused by substances belonging to the polyphenole group (for example, tannins) or by other compounds in the plant that are ingested by the nymphs. Several studies on phenolic pear compounds are known from literature (Chalisse and Williams, 1968; Gerard *et al.*, 1993).

With regard to the presence of compounds belonging to the flavone glycoside group in pear, Chalisse and Williams (1968) noticed that a difference exists between *P. communis* and *P. ussuriensis*: the compounds were not detected in the former, native to Europe, but they were present in the latter, native to Asia. Nymphal antibiosis is associated with a decrease in the feeding frequency, which could be due to the presence of feeding inhibitors (Butt *et al.*, 1989) or due to an insufficient feeding stimulus of the plant. The inadequate feeding stimulus could be due to differences in the polar and lipidic fraction of the leave extract of the different resistant and susceptible varieties (Chang and Philogène, 1978).

Figure 1. Tunnel used for choice test.

Scutareanu *et al.* (1999) showed that, in response to an attack of *C. pyricola* and *C. pyri*, the production of *3-O-trans-p-cumaroyltormentic acid,* a new phenolic compound, is induced. This compound is already present 12 hours after the attack, and reaches its peak after 30 days. Scutareanu *et al.* (2001) also demonstrated that its induction is local ('Conference') or systemic ('William' and NY 10355). Puterka *et al.* (1993) showed that in resistant genotypes both resistance traits, ovipositional antixenosis and nymphal antibiosis, can often be found together. Since in some genotypes only one of the two resistance traits exists, the two characters must be indipendent on a genetic level.

The aim of this study was to evaluate the resistance to *C. pyri* of different pear selections using phenotypical scrennings. Antixenosis, which arises from the settling of the adults and their reduced oviposition rates, and nymphal antibiosis were recorded using free choice tests.

One selection may not be preferred over an other in the case of free choice, but in the case of no choice, such as in a pear orchard, the host may be attacked by the pest. We therefore decided to conduct also no choice tests, because they allow to assess for relative ovipositional antixenosis.

Materials and methods

In 2003, 2004, and 2005, the resistance to *C. pyri* of different selections was evaluated by determing the settling of adults, the nymphal feeding response, and the ovipositional response of the females on the different selections using a free-choice test. *C. pyri* adults (males and females) were introduced in a mesh-covered tunnel containing pear plants of the different selections (figure 1), and the number of adults colonizing the plants (settling), the number of eggs laid, and the feeding response of the nymphs was then recorded. In 2004, we assessed for oviposition also using no choice tests.

Free-choice tests

Plants and insects

Every study year, at the end of winter, the plants of the different selections were grafted onto quince rootstocks, and then transferred into pots. The different selections or genotypes, consisting of intraspecies crosses of *P. communis* and of interspecies crosses between *P. communis* and *P. ussuriensis* and between *P. communis* and *P. pyrifolia* (table 1), were provided by the ISF-FO and by the DCA.

Test insects were summer-form *C. pyri* adults (males and females), which had been collected in a pear orchard (cv. Williams) using a small mouth-aspirator.

The screening started in June 2003 inside an anti-aphid screen tunnel (3 x 10 x 2.5 m), covered with a reflective sheet to reduce inside temperature (figure 1). The bottom of the tunnel was covered with a heavy, black anti-algae sheet. Fifteen selection, each replicated from 5 to 13 times, were tested in 2003, whereas 16 se-

Table 1. Selections tested in 2003, 2004 and 2005 (P. u = *P. ussuriensis*; P. c = *P. communis*; P. p = *P. pyrifolia*).

Selection	Parents	♀ origin	♂ origin	2003 (reps.)	2004 (reps.)	2005 (reps.)
William		P. c	P. c	8	12	9
NY 10353	NY 10257 x Russet Flemish Beauty	(P. c x P. u)	P. c	8	14	8
Spina Carpi		P. c	P. c	5	-	-
DCA 93052105-119	NY 10353 x Doyenne du Comice	(P. c x P. u) x P. c	P. c	8	16	-
DCA 92052203-12	NY 10355 x Max Red Bartlett	(P. c x P. u) x P. c	P. c	9	-	-
DCA 92052203-2	NY 10355 x Max Red Bartlett	(P. c x P. u) x P. c	P. c	8	-	-
DCA 92052103-55	NY 10353 x Max Red Bartlett	(P. c x P. u) x P. c	P. c	10	-	-
DCA 92052103-9	NY 10353 x Max Red Bartlett	(P. c x P. u) x P. c	P. c	13	-	-
ISF FO 80-51-72	Coscia x Guyot	P. c	P. c	8	-	-
ISF FO 80-91-01	Doyenne du Comice x Conference	P. c	P. c	10	-	-
ISF FO 80-104-72	Coscia x Guyot	P. c	P. c	6	-	-
ISF FO 80-57-83	Conference x Guyot	P. c	P. c	12	-	-
ISF FO 80-6-108-71	Coscia x Bella di Giugno	P. c	P. c	-	8	-
ISF FO 80-87-81	Conference x Abbé Fetel	P. c	P. c	-	12	7
ISF FO 90-5-70-150	Tosca x Shinseiki	P. c	P. p	-	13	-
ISF FO 90-4-124-152	Coscia x Shinseiki	P. c	P. p	-	10	-
ISF FO 80-157-71	Coscia x Bella di Giugno	P. c	P. c	-	14	-
ISF FO 90-12/110-149	Tosca x Tama	P. c	P. p	5	-	-
ISF FO 94-4/130-267	NY 10357 x 80-6-91	(P. c x P. u) x P. c	P. c	12	13	-
ISF FO 94-1/174-267	NY 10357 x 80-6-91	(P. c x P. u) x P. c	P. c	-	-	10
ISF FO 94-5-51-268	80-6-91 x NY 10357	P. c	(P. c x P. u) x P. c	-	-	7
ISF FO 94-4/103-267	NY 10357 x 80-6-91	(P. c x P. u) x P. c	P. c	-	-	9
ISF FO 89-9/90-133	NY 10355 x Tosca	(P. c x P. u) x P. c	P. c	5	15	-
DCA 92052103-43	NY 10353 x Max Red Bartlett	(P. c x P. u) x P. c	P. c	-	15	-
DCA 9105701-39	Abbé Fetel x US 309	P. c	P. c	-	12	-
DCA 93052105-115	NY 10353 x Doyenne du Comice	(P. c x P. u) x P. c	P. c	-	8	-
DCA 90050708-9	US 309 x Osa Nijisseiki	P. c	P. p	-	9	10
DCA 93052105-207	NY 10353 x Doyenne du Comice	(P. c x P. u) x P. c	P. c	-	8	-
DCA 92051124-8	Harwest Queen x William	P. c	P. c	-	12	-
ISF FO 68-20-5-11	Coscia x William	P. c	P. c	-	-	8
ISF FO 68-3F-140-11	Coscia x William	P. c	P. c	-	-	10
DCA 91050110-51	Abbé Fetel x Cascade	P. c	P. c	-	-	5
DCA 92050110-69	Abbé Fetel x Cascade	P. c	P. c	-	-	11
DCA 9105701-41	US 309 x Abbé Fetel	P. c	P. c	-	-	9
DCA 91050701-14	US 309 x Abbé Fetel	P. c	P. c	-	-	10
DCA 90050103-44	Abbé Fetel x Max Red Bartlett	P. c	P. c	-	-	10

lections, each replicated from 8 to 16 times, were tested in 2004, and 14 selection, each replicated from 5 to 11 times, in 2005 (table 1).

Once the test plants had reached adequate size and vegetative state (from 50 to 70 cm in height, with one or two shoots), they were placed inside the tunnel in a random pattern. A drip irrigation system was used to water the plants. In 2003 and 2005, 300 *C. pyri* adults were released inside the tunnel, while 400 adults were released in 2004 (sex ratio ♂♂:♀♀ ≅ 1:1; approximately one female per plant).

Settling of adults

10, 25, and 50 days after the release, the number of adults (♂♂ and ♀♀) on each plant was counted in order to determine the mean number of adults on each selection.

Ovipositional response

The number of eggs laid on each plant was counted 10 and 25 days after the release, and the mean number of eggs laid on the different selection was calculated.

Feeding response

The *C. pyri* feeding response was estimated by counting the number of nymphs producing honeydew on each plant 25 and 50 days after the release.

No-choice tests

Plants and insects

The same selections used in the 2003-free choice test were used in the no-choice test to assess for the ovipositional response.

The trial was carried out in a greenhouse. One psylla female (3 to 11 replicates per selection) was kept on the upper surface of a leaf inside a "clip-cage" (figure 2).

The number of eggs laid by each female was counted 48 and 72 hours after having placed the female on the leaves.

Statistical analysis

In the free-choice tests, for each sampling date, the number of adults, the number of eggs laid, and the number of nymphs producing honeydew were compared across selections using the non parametric analysis of variance Kruskal-Wallis test (STATISTICA® 6.0).

Figure 2. Clip-cage used for no-choice test.

Table 2. 2003: statistical summary of the Kruskal-Wallis test.

Trait	Days after release of adults	H (Kruskal-Wallis test)	p level
Settling of adults	10	7.95	0.89
	25	21.81	0.08
	50	15.80	0.32
Ovipositional response	10	18.46	0.18
	25	15.21	0.36
Feeding response	25	20.81	0.10
	50	16.70	0.27

Also the number of eggs laid by the females in the no-choice test was compared across selections using the Kruskal-Wallis test (STATISTICA® 6.0).

Means are reported with their standard error.

Results

Free-choice tests

2003

Settling of adults:

For the settling of adults (mean no. adults per plant), differences among selections were significant neither 10, nor 25, nor 50 days after the release (table 2). However, in general, less adults were found on *P. ussuriensis* x *P. pyrifolia* selections than on *P. communis* selections (figures 3a, b and c). At the beginning (T + 10), the old Italian *P. communis* variety ‘Spina Carpi’, resistant to psylla, did not show antixenosis effects on *C. pyri* adults.

Ovipositional response:

No significant differences among selections emerged in the number of eggs laid 10 and 25 days after the release of the adults inside the tunnel (table 2). Neither at 10 nor at 25 days from the release, any eggs were found on the selections NY 10353 and ISF FO 90-12-110-149, whereas on the selections DCA 93052103-119 and DCA 92052103-9 eggs were detected only at the first sampling date (figures 4a and b).

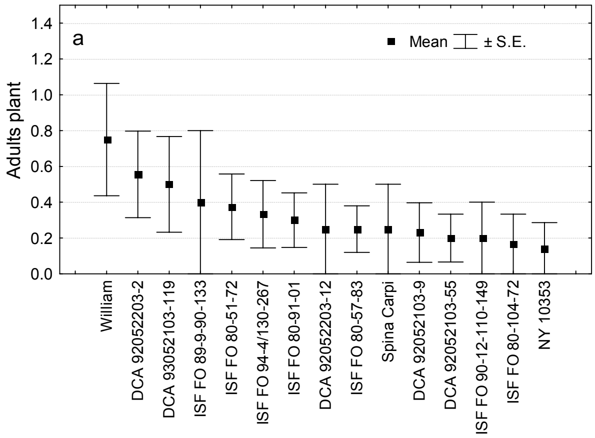

Figure 3a. Number of adults 10 days after adults release (2003).

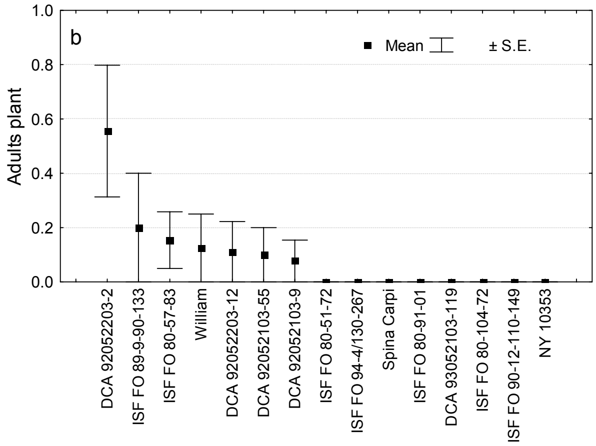

Figure 3b. Number of adults 25 days after adults release (2003).

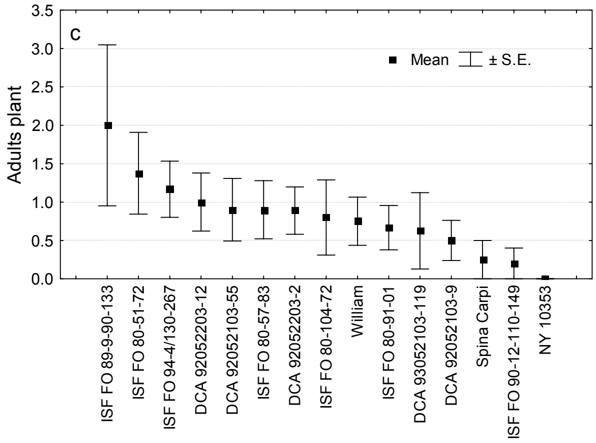

Figure 3c. Number of adults 50 days after adults release (2003).

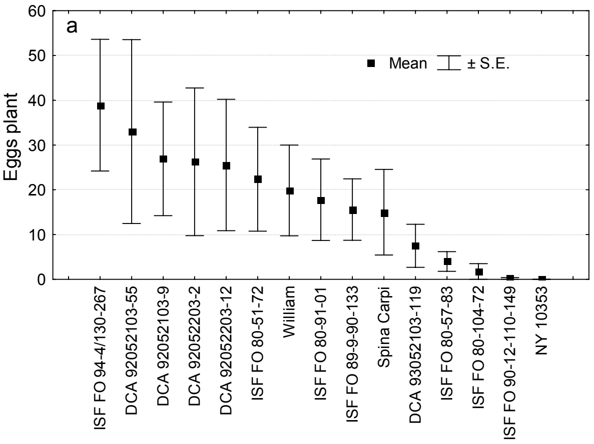

Figure 4a. Number of eggs 10 days after adults release (2003).

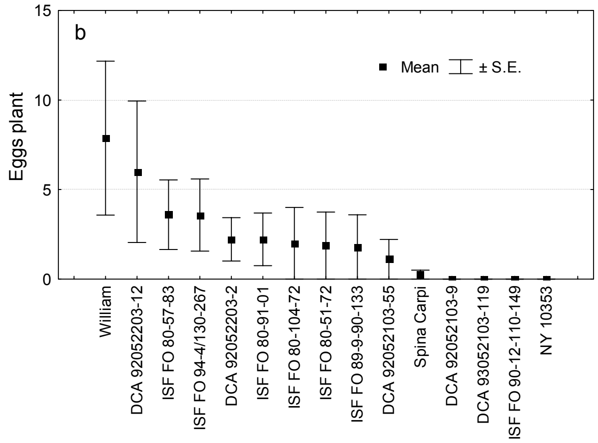

Figure 4b. Number of eggs 25 days after adults release (2003).

When comparing the percentage of plants not suitable to adults and that of plants not suitable to oviposition, except for the selections NY 10353 (*P. ussuriensis* x *P. communis*) and ISF FO 90-12-110-149 (*P. pyrifolia* x *P. communis*), for the other selections tested no high reciprocity between the two percentages was observed (figure 5): more eggs should be laid on selections with a higher number of settled adults. This indicates that the adults choose their host for oviposition more so than they do for settling.

Feeding response:

Also for the feeding response (no. nymphs producing honeydew), differences among selections at 25 and 50 days after the release of the adults were not significant (table 2). However, considerably less nymphs were found feeding on the plants of the selections containing *P. ussuriensis* and *P. pyrifolia* as parents, and 'Spina Carpi', respectively, than on the plants of all the other selections (figure 6). The selection DCA 93052103-119 showed pronounced antibiosis effects, similar to those of its parent NY 10353; it thus completely inherited the resistance traits from its parent. The selection 94-4/130-267 (cross between 80-6-91 and NY 10257) seems able to limit nymphal feeding only at a later date (T + 50).

The selections DCA 92052203-12 and DCA 92052203-2, both crosses between 'Max Red Bartlett' and NY 10355, and the selection DCA 92052103-55, a cross between 'Max Red Bartlett' and NY 10353 (table 1) did not exhibit any resistance traits to *C. pyri*, and thus the transfer of the traits from resistant selections not occur.

DCA 92052103-9, an other cross between 'Max Red Bartlett' and NY 10353, showed moderate resistance to *C. pyri*: nymphal survival was scarce (figures 6a and b), but oviposition was not limited (figure 4a).

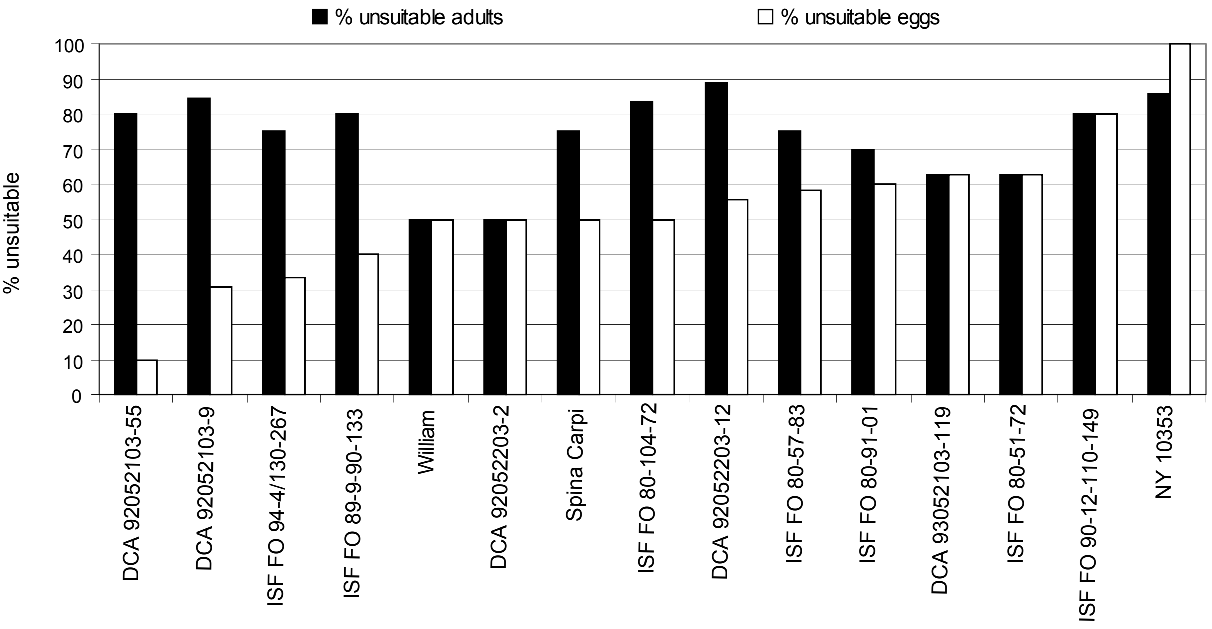

Figure 5. Comparison between settling of the adults and ovipositional response (2003).

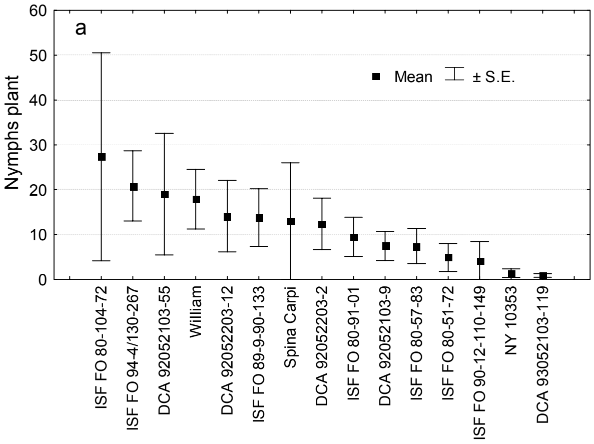

Figure 6a. Number of nymphs 25 days after adults release (2003).

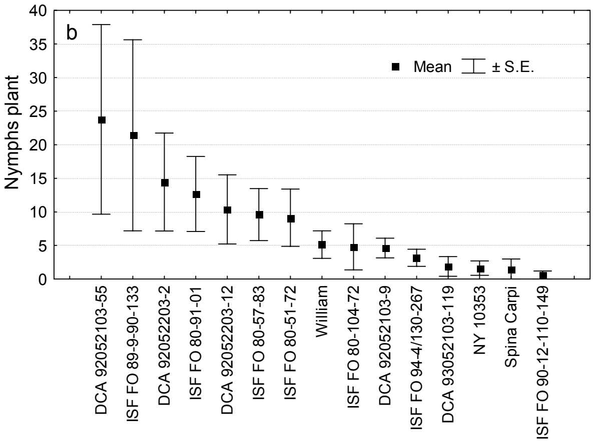

Figure 6b. Number of nymphs 50 days after adults release (2003).

Table 3. 2004: statistical summary of the Kruskal-Wallis test.

Trait	Days after release of adults	H (Kruskal-Wallis test)	p level
Settling of adults	10	36.14	0.00
	25	9.59	0.84
	50	43.56	0.00
Ovipositional response	10	41.51	0.00
	25	11.93	0.68
Feeding response	25	62.80	0.00
	50	70.35	0.00

2004

Those selections that did not show any resistance trait in 2003, were not tested in 2004.

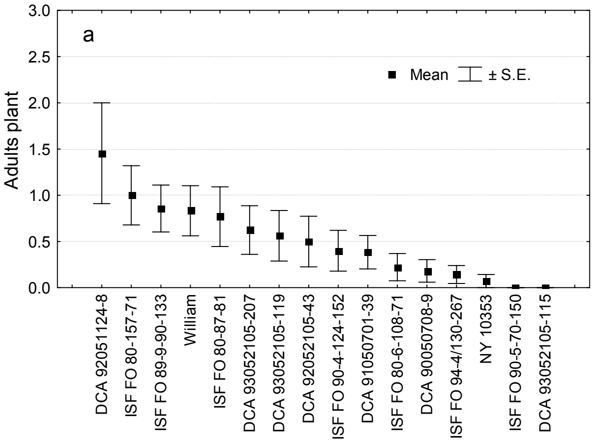

Figure 7a. Number of adults 10 days after adults release (2004).

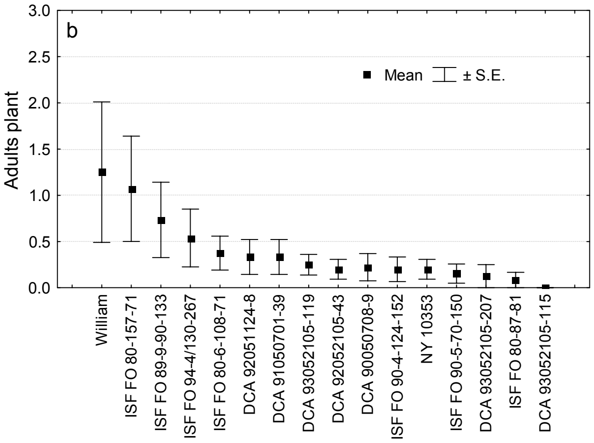

Figure 7b. Number of adults 25 days after adults release (2004).

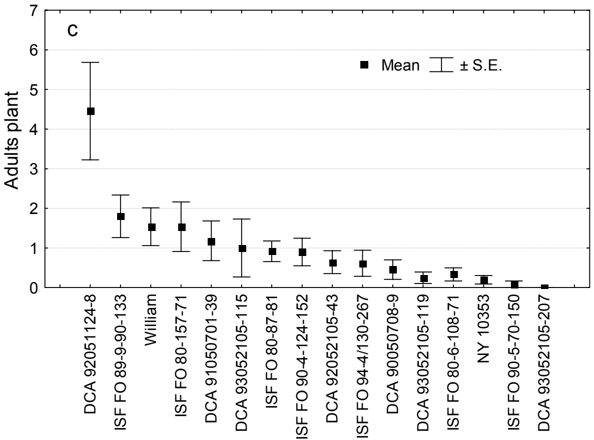

Figure 7c. Number of adults 25 days after adults release (2004).

Settling of adults:

For the settling of adults, differences among selections were significant at 10 and 50 days from the release of the adults, but not at 25 days (table 3). In general, less psylla adults were recorded on the selections that were crosses between *P. ussuriensis* and *P. pyrifolia* than on *P. communis* selections (figures 7a, b and c).

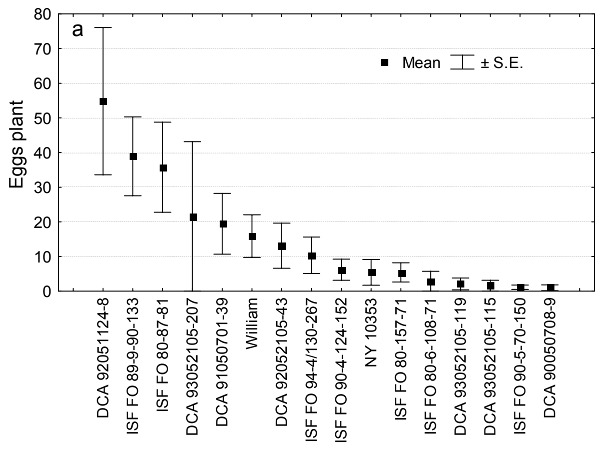

Figure 8a. Number of eggs 10 days after adults release (2004).

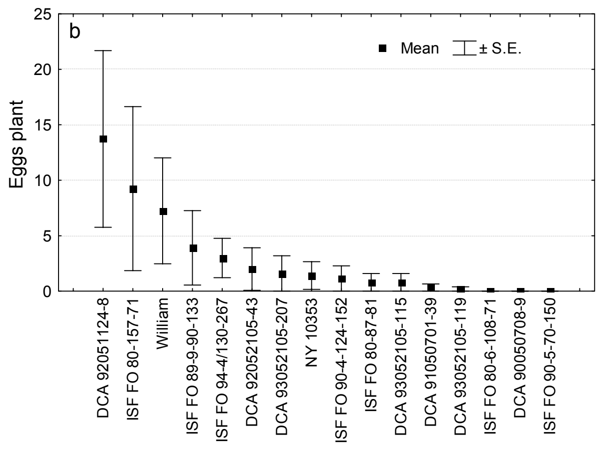

Figure 8b. Number of eggs 25 days after adults release (2004).

Ovipositional response:

For the number of eggs laid, significant differences among selections emerged on the first assessment date (10 days from the release of the adults), but not on the second (25 days from the release) (table 3). Especially on the first assessment date, (figures 8a and b) a lower number of eggs was found on the selections DCA 93052105-115 and DCA 93052105-119, crosses between NY 10353 (Resistant) and ‘Doyenne du Comice’ (Susceptible), and on the two selections that are crosses between Tosca (Susceptible), US 309 (Susceptible) and selections of *P. pyrifolia*.

Also in 2004, for the different selections, the percentage of plants not suitable to adults was not always consistent with that of the plants not suitable to oviposition (figure 9), confirming a less pronounced choice behaviour by adults with regard to settling than to oviposition.

Feeding response:

For the number of nymphs producing honeydew, both 25 and 50 days after the release of the adults (figures 10a and b), highly significant differences among selections were recorded (table 3). The selection DCA 93052103-119 showed high resistance to *C. pyri*, confirming the results obtained in 2003. In 2003, for the hybrid selections ISF FO 89-9/90-133 and ISF FO 94-4/130-247, the results concerning the three investigated resistance traits were not clear, but the 2004-results evidenced that these two selections do not have any of these traits.

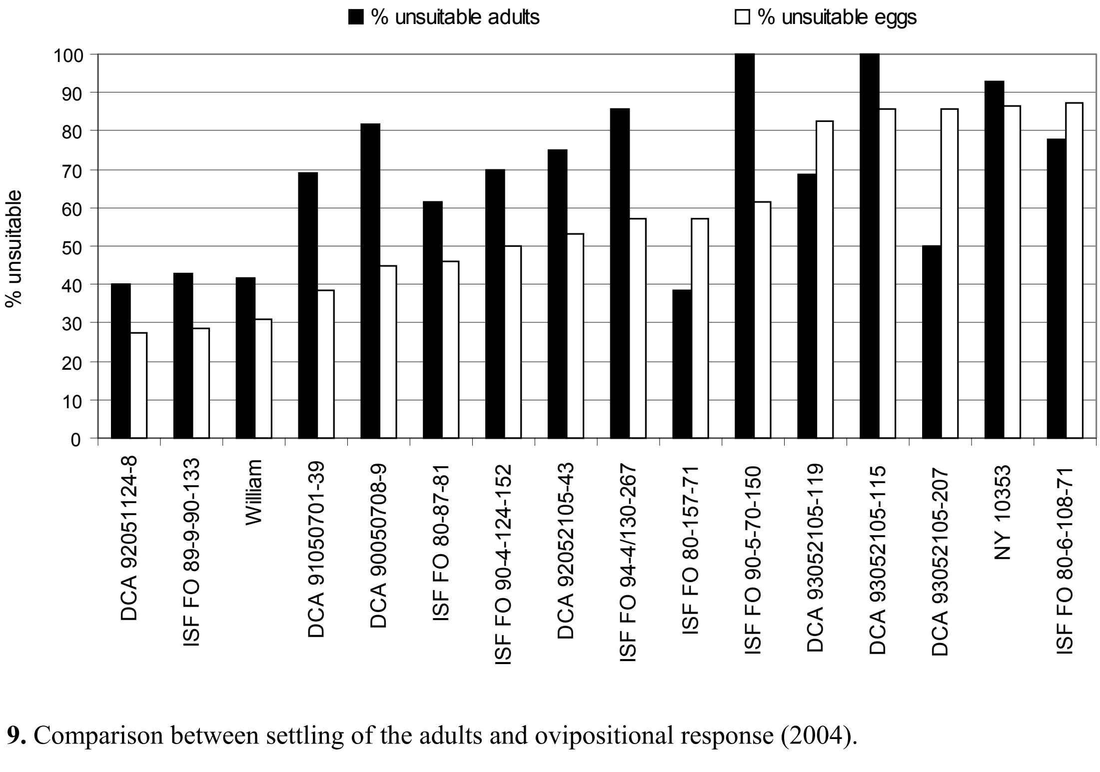

Figure 9. Comparison between settling of the adults and ovipositional response (2004).

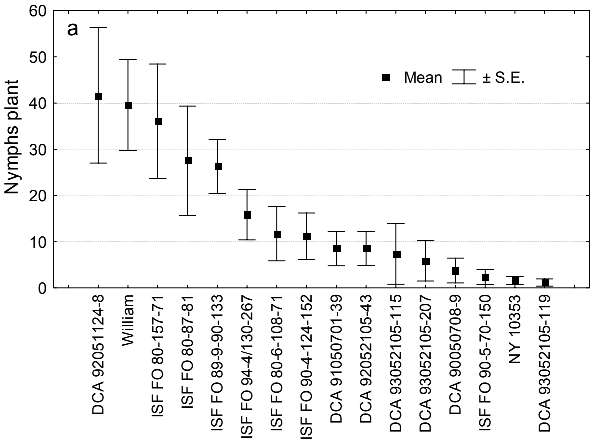

Figure 10a. Number of nymphs 25 days after adults release (2004).

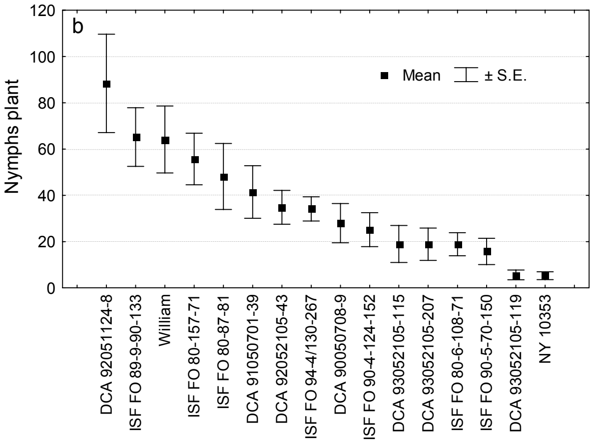

Figure 10b. Number of nymphs 50 days after adults release (2004).

Table 4. 2005: statistical summary of the Kruskal-Wallis test.

Trait	Days after release of adults	H (Kruskal-Wallis test)	p level
Settling of adults	10	14.48	0.34
Ovipositional response	10	31.40	0.00
Feeding	25	29.71	0.05
response	50	19.39	0.11

2005

Settling of adults:

Even though differences among selections in the number of settled adults 10 days after the release were not significant, an extremely low number of adults was usually present on selections with *P. ussuriensis* as parental genotype (table 4; figure 11).

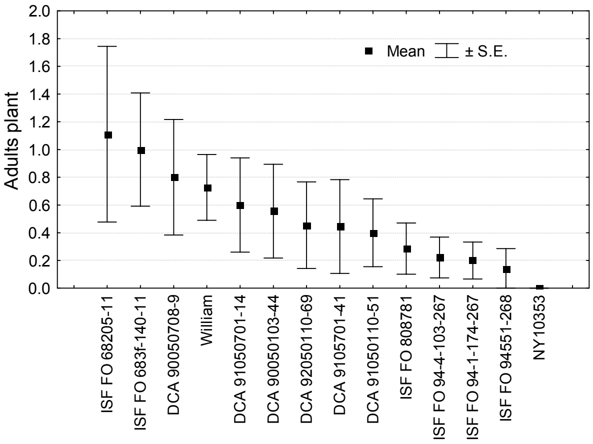

Figure 11. Number of adults 10 days after adults release (2005).

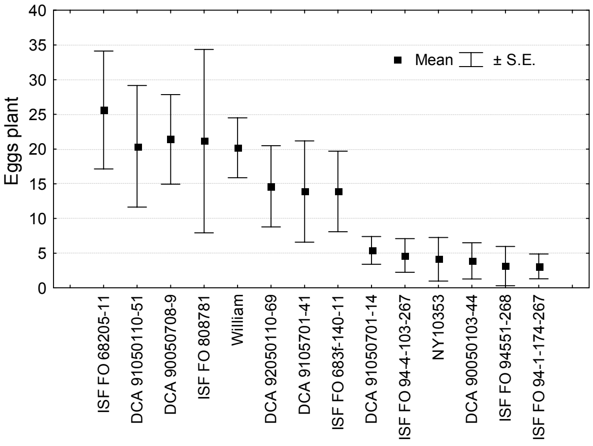

Figure 12. Number of eggs 10 days after adults release (2005).

Ovipositional response:

Significant differences among selections in the ovipositional response 10 days after the release of the adults were recorded (table 4). Also in this case, the lowest number of eggs laid per plant was observed on selections of *P. ussuriensis*, such as ISF FO 944103-267, ISF FO 94551-268, ISF FO 941174-267, and NY 10353 (figure 12).

Feeding response:

Differences among selections in the number of nymphs producing honeydew were significant 25 days after the release of the adults, but failed significance on the second assessment date (50 days after adult release) (table 4). On the first assessment date, those selections that showed ovipositional antixenosis did not show nymphal antibiosis (figure 13a). A similar trend was observed on the second assessment date (figure 13b).

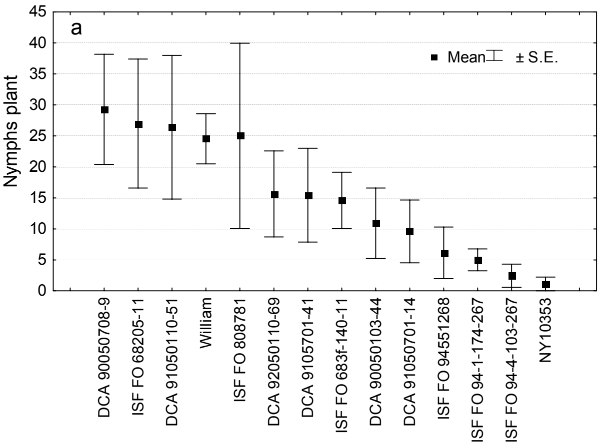

Figure 13a. Number of nymphs 25 days after adults release (2005).

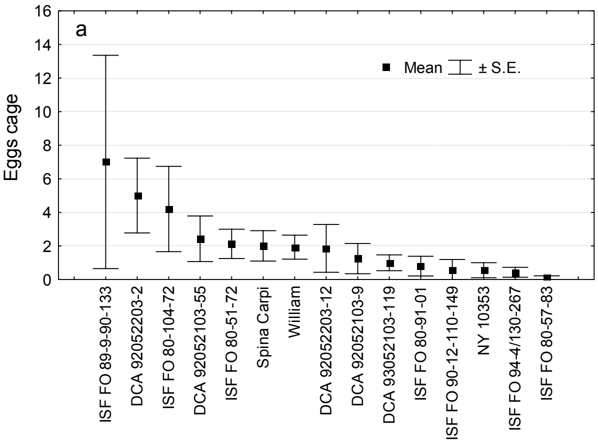

Figure 14a. Number of eggs 48 h after adult release in clip-cage.

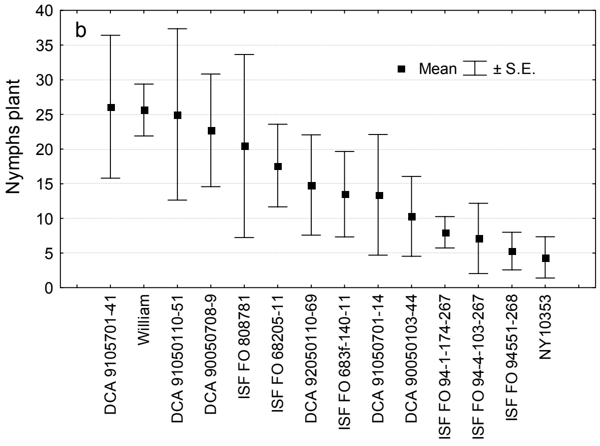

Figure 13b. Number of nymphs 50 days after adults release (2005).

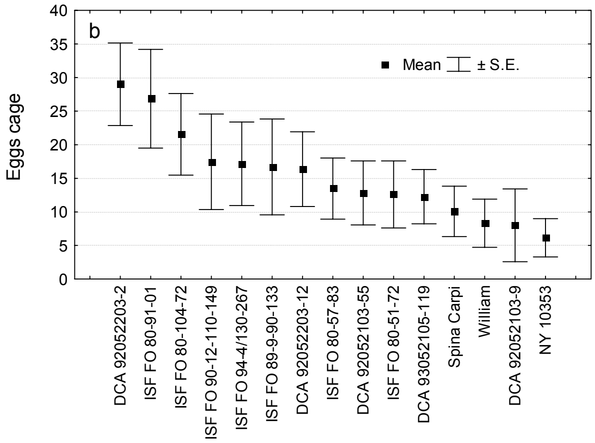

Figure 14b. Number of eggs 72 h after adult release in clip-cage.

Table 5. 2004: statistical summary of the Kruskal-Wallis test.

trait	H (Kruskal-Wallis test)	p level
Ovipositional response after 48 h.	14.88	0.38
Ovipositional response after 72 h.	10.13	0.75

No-choice test

2004

Ovipositional response:

In the case of no choice, the ovipositional response of the *C. pyri* females (figure 2) did not differ significantly among selections (table 5). Therefore, over a short period of time (48-72 h) and in confined environments, the *C. pyri* females are probably not able to clearly discriminate between a susceptible and a resistant selection. This could be due to the absence of resistance mechanisms on the level of volatile substances in the head space and/or on the level of the leaf surface. In fact, the selction ISF FO 90-12/110-149, a hybrid obtained crossing Tosca x Tama (*P. pyrifolia*), was highly resistant to oviposition in the choice test (figures 2a and b), but had the highest number of eggs in the no-choice test (figures 14a and b).

Conclusions

With regard to the transfer of resistance traits (mainly antibiosis effect) from resistant selections, among the selections obtained from crosses with resistant NY selections, those obtained from crosses with NY 10353 and Doyenne du Comice or NY 10357 and 80-6-91 were the most resistant (table 6), while no resistance was recorded when NY 10353 or NY 10355 were crossed with Max Red Bartlett. Only DCA 92052103-9 showed slight resistance.

With regard to the transfer of resistance from *P. pyrifolia*, except DCA 90050708-9 and ISF FO 90-4-124-152, all the other tested selections showed a high degree of resistance to *C. pyri* (table 7).

The transfer of resistance to *C. pyri* in interspecies crosses between the European pear species *P. communis* (Susceptible) and Asian pear species (Resistant), such as

Table 6. Transfer of resistance traits in crosses with different NY selections.

Cross	Selection	Status
NY 10353 x Doyenne du Comice	DCA 93052105-119	Resistant
	DCA 9305215-115	Medium resistant
	DCA 93052105-207	Medium resistant
NY 10353 x Max Red Bartlett	DCA 92052103-55	Susceptible
	DCA 92052103-9	Medium resistant
NY 10355 x Max Red Bartlett	DCA 92052103-43	Medium susceptible
	DCA 92052103-12	Susceptible
	DCA 92052103-2	Susceptible
NY 10355 x Tosca	ISF FO 89-9/90-133	Susceptible
NY 10357 x 80-6-91	ISF FO 94-4/130-267	Medium susceptible
	ISF FO 94-1/174-267	Resistant
	ISF FO 94-4/103-267	Resistant
80-6-91 x NY 10357	ISF FO 94-5-51-268	Resistant

Table 7. Transfer of resistance traits in crosses with different selections of *P. pyrifolia*.

Cross	Selection	Status
Tosca x Shinseiki	ISF FO 90-5-70-150	Resistant
Coscia x Shinseiki	ISF FO 90-4-124-152	Medium susceptible
Tosca x Tama	ISF FO 90-12/110-149	Resistant
US 309 x Osa Nijisseiki	DCA 90050708-9	Susceptible

P. ussuriensis and *P. pyrifolia*, to part of the progeny is possible, as already observed in previous studies (Westigard *et al*., 1970; Harris and Lamb, 1973; Quamme, 1984; Bell and Stuart, 1990). The transfer occurs gradually, and is probably controlled by several genes and not only by one single gene (*gene major*).

The settling of adults, ovipositional antixenosis, and nymphal antibiosis are the three traits that we observed in the resistant selections. Among these traits, the most important one is nymphal antibiosis, which precociously causes death in 1-2 week-old nymphs. Furthermore, the nymphs produce a low amount of honeydew. The other two traits, i.e. ovipositional antixenosis and settling of adults, are less important, and are probably due to a prevalent localization of the resistance mechanisms within the tissues of the leaves rather than on their outside (surface and volatile compounds in the head space). Olfactometric and EPG-DC studies to investigate this hypothesis are in progress. Horton and Krysian (1990, 1991) noticed that in *C. pyricola* the ovipositional activity of the adults is more selective than their *settling* and *probing* activity: *C. pyricola* can colonize and feed on non optimal hosts, such as *P. calleryana* and *Malus* spp., but they do not lay eggs.

Interpreting the results of these screenings was extremely difficult because of the high variability among plants of the same selection, or in the case the repetition number was too low. This variability could be due to the phenotypic variability, which eventually can affect the results of the experiments. A genotypic selection using molecular markers (MAS) could improve the screening method. For those selections that were shown to be resistant or medium resistant, further agronomic evaluations are needed in order to establish their actual potential for the pear genetic improvement.

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References

BALDASSARI N., BARONIO P., ROCCHETTA G., SALVATERRA I., 1996.- Indagine sullo sviluppo di *Cacopsylla pyri* (L.) (Hemiptera Psyllidae) su differenti mutanti e selezioni di pero.- *Bollettino dell'Istituto di Entomologia "Guido Grandi" della Università degli Studi di Bologna*, 50: 201-213.

BELL R. L., 1984.- Evaluation of *Pyrus* germplasm for resistance to pear psylla.- *Acta horticulturae*, 161: 234-237.

BELL R. L., STUART L. C., 1990.- Resistance in Eastern European *Pyrus* germplasm to pear psylla nymphal feeding. *HortScience*, 25 (7): 789-791.

BELLINI E., NIN S., 2000.- Pear breeding for new trails in pear, pp. 57-79. In: *Abstract VIII International Symposium on Pear*, 4-9 September 2000 Ferrara-Bologna, Italy.

BUTT B. A., STUART L. C., BELL R. L., 1988.- Feeding beaviour of pear psylla (Homoptera: Psyllidae) nymphs on susceptible and resistant *Pyrus* germplasm.- *Journal of Economic Entomology*, 81: 1394-1397.

BUTT B. A., STUART L. C., BELL R. L., 1989.- Feeding longevity and development of pear psylla (Homoptera: Psyllidae) nymphs on resistant and susceptible pear genotipes.- *Journal of Economic Entomology*, 82: 458-461.

CHALICE J. S., WILLIAMS A. H., 1968.- Phenolic coumpounds of the genus *Pyrus*-1.- *Phytochemistry*, 7: 119-130.

CHANG J. F., PHILOGÈNE B. J. R., 1978.- Response of *Psylla pyricola* (Homoptera: Psyllidae) to, and characterization of polar and lipid fractions of *Pyrus* sp. leaves.- *Phytoprotection*, 59 (1): 28-39.

GERARD H. C., FETT W. F., MOREAU R. A., OSMAN F. S., MILLER R. L., 1993.- Chemical and enzymic investigation of the leaf cuticle of pear genotypes differing in resistance to pear psylla.- *Journal of Agricultural and Food Chemistry*, 41: 2437-2441.

HARRIS M. K., 1973.- Host resistance to pear psylla in a *Pyrus comunis* x *Pyrus ussuriensis* hybrid.- *Environmental Entomology*, 2 (5): 883-887.

HARRIS M. K., LAMB R. C., 1973.- Resistance to the pear psylla in pears with *Pyrus ussuriensis* lineage.- *Journal of the American Society for Horticultural Science*, 98 (4): 378-381.

HORTON D. R., KRYSIAN J. L., 1990.- Probing and oviposition-related activity of summerform pear psylla (Homoptera: Psyllidae) on host and nonhost substrates.- *Environmental Entomology*, 19 (5): 1463-1468.

HORTON D. R., KRYSIAN J. L., 1991.- Host acceptance behavior of pear psylla (Homoptera: Psyllidae) affected by plant species, host deprivation, habituation, and eggload.- *Annals of the Entomological Society of America*, 84 (6): 612-627.

MILLER R. L., BILLS D. D., BUTTERY R. G., 1989.- Volatile components from Bartlett and Bradford pear leaves.- *Journal of Agricultural and Food Chemistry*, 37: 1476-1479.

PUTERKA G. J., BELL R. L., JONES S. K., 1993.- Ovipositional preference of pear psylla (Homoptera: Psyllidae) for resistant and susceptible pear.- *Journal of Economic Entomology*, 86: 1297-1302.

PUTERKA G. J., BOCCHETTI C., DANG P., BELL R. L., SCORZA R., 2002.- Pear transformed with a lytic peptide gene for disease control affects nontarget organism, pear psylla (Homoptera: Psyllidae).- *Journal of Economic Entomology*, 95 (4): 797-802.

QUAMME H. A., 1984.- Observations of Psylla resistance among several pear cultivars and species.- *Fruit Varieties Journal*, 38 (2): 34-36.

RIVALTA L., DRADI M., 1998.- Miglioramento genetico del pero presso l'Istituto Sperimentale per la Frutticoltura di Forlì.- *Rivista di Frutticoltura*, 9: 51-57.

ROBERT P., RAIMBAULT T., 2005.- Resistance of some *Pyrus communis* cultivars and *Pyrus* hybrids to the pear psylla *Cacopsylla pyri* (Homoptera, Psyllidae).- *Acta Horticulturae,* 671: 571-575.

ROBERT P., CHAUSSET J., LE LEZEC M., 1999.- Larval development of *Cacopsylla pyri* (L.) (Homoptera: Psyllidae) on two resistant *Pyrus* genotypes.- *IOBC/wprs Bulletin*, 22 (10): 89-91.

ROBERT P., GUERIF P., LEMOINE J., LE LEZEC M., 2004.- Criblage de génotypes de Pyrus vis-a-vis de la résistance au psylle du poirier *Cacopsylla pyri* (L.).- *Cahiers Agricultures*, 13: 349-354.

SCUTAREANU P., MA Y., CLAEYS M., DOMMISSE R., SABELIS M. W., 1999.- Induction of a p-cumaroyl trihydroxy triterpene acid in *Psylla*-infested and mechanically damaged pear trees.- *Journal of Chemical Ecology*, 25 (9): 2177-2191.

SCUTAREANU P., SABELIS M. W., BOON J. J., 2001.- Systemic and non-systemic responses induced by herbivory: variation among pear cultivars.- *IOBC/wprs Bulletin*, 24 (5): 227-234.

WESTIGARD P. H., WESTWOOD M. N., LOMBARD P. B., 1970.- Host preference and resistance of *Pyrus* species to the pear psilla *Psylla pyricola* Foerster.- *Journal of the American Society for Horticultural Science*, 95 (1): 34-36.

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