Assessment of the susceptibility to pests and diseases of 36 apple cultivars in four low-input organic orchards in France

C-E. Parveaud[1], C. Gomez[1], G. Libourel[2], L. Romet[2], F. Warlop[2], S. Simon[3], L. Brun[3], D. Pouzoulet[4], A. Delebecq[5], L. Tournant[6], S. Oste[6], F. Laurens[7].

Abstract

One of the keystones of the organic orchard is the cultivar choice as one element of pest and disease control. However, few exhaustive data sets concerning the cultivar susceptibility to pests and diseases are available for growers. In order to identify cultivars adapted to organic production methods, the susceptibility to scab, aphids and powdery mildew and the agronomic properties of 36 cultivars were assessed in four French sites under different pedo-climatic conditions. Different levels of susceptibility to scab were observed for 23 scab Vf*-resistant and 13 other cultivars. In the North of France where* Vf *resistance is overcome, the Vf cultivars displayed different levels of scab severity. A high variability in the susceptibility to aphids was observed whereas susceptibility to powdery mildew varied less. The analysis of susceptibility properties, yield and fruit quality, fruit storability and tree behaviour permitted to identify a set of interesting cultivars according to the site.*

Keywords: susceptibility, scab, aphids, powdery mildew, apple cultivar

Introduction

A national programme has been set up in 2001 with the financial support of the French Ministry of Agriculture in order to assess the possibilities of managing low-input organic apple and pear orchards. During the last decades, breeders have selected apple cultivars which have mainly been assessed on yield, fruit quality and storability characteristics, and consumer perception. The susceptibility to diseases and pests was not considered as a key criterion. Because scab is one of the most serious diseases in different production areas, the cultivar susceptibility to this disease has been integrated for long in breeding programmes. However, other pests and diseases such as aphids or powdery mildew are poorly considered. As a consequence, the characteristics of most of the commercial cultivars do not fit the organic growers' demand. However, the choice of the cultivar in organic cropping systems is a key decision because it will strongly influence disease and pest management which is one of the bottlenecks and main challenges in organic apple production (Trapman and Jansonius, 2008).

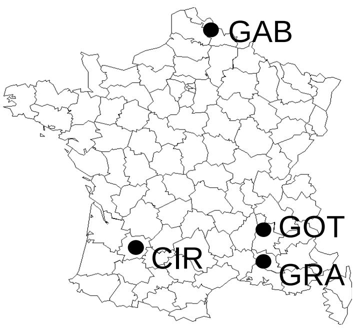
In order to help the growers in their choice of apple cultivars, the susceptibility to pests and diseases and the agronomic interest of a wide range of apple cultivars was assessed. Susceptibility to aphids, scab and powdery mildew was quantified. Moreover, agronomic parameters such as tree behaviour with natural habit, yield, fruit quality and storability

[1] GRAB, Research Group for Organic Farming, France, 26320 Saint-Marcel-les-Valence, claudeeric.parveaud@grab.fr
[2] GRAB, Research Group for Organic Farming, France, 84911 Avignon Cedex 9, gilles.libourel@grab.fr
[3] INRA, UERI Gotheron, France, 26320 Saint-Marcel-les-Valence, lbrun@avignon.inra.fr
[4] CIREA, France, 47360 Prayssas, mr.cirea47@wanadoo.fr
[5] GABNOR, France, 59133 Phalempin, alain.delebecq@gabnor.org
[6] FREDON Nord-Pas-de-Calais, France, 62750, Loos-en-Gohelle, ludovic.tournant@fredon-npdc.com
[7] INRA, UMR GenHort, France, 49071 Beaucouzé Cedex, laurens@angers.inra.fr

were assessed (Gomez *et al.*, 2006). In the present paper, we will focus on cultivar susceptibility to pests and diseases.

Material and Methods

In 2002, 1357 trees of 36 apple cultivars were planted in 4 French sites under different pedo-climatic conditions (Figure 1). 9 cultivars came from genetic resources centers, 13 were commercial cultivars and 14 were recent hybrids. Among the cultivars selected in this study, 23 cultivars were *Vf* resistant to scab and 13 were not.



Soil types
GAB: Deep silt
GOT: Clay and silt with stones
GRA: Limestone alluvium, silt and clay
CIR: Clay

Figure 1: Location of the four sites in France: GABNOR and others partners (GAB); INRA Gotheron and GRAB (GOT); GRAB (GRA) and CIREA (CIR). Scientific and technical management was realized by F. Laurens and G. Libourel respectively.

In GOT, GRA and CIR sites, M7 or PI80 rootstocks were used according to cultivar vigour. Trees on M7 rootstocks were staked and trees on PI80 were tied in. In the GAB site, M106 and Pajam rootstocks were also used.

Orchard management was realized in order to minimize inputs (Table 1). Pest and disease control was managed by risk assessments in orchards combined with climatic risk. Preventive methods were used preferentially to systemic sprays. Pesticide applications were only used along high infection and infestation risk periods and the number of treatments was limited. Others practices such as pruning, fertilizing or weed management were limited in time or in repetitions.

Table 1: Orchard management realized at the four sites.

Planting distances	M7: 4.5 x 2.4m - 6.0 x 4.0m; PI80: 4.5 x 1.7m - 5.0 x 2.0 m
Fertilizing and irrigation	Without any restriction in the first year, then adapted to tree requirements. Organic supplies (compost, organic manure, feather manure) provided 0 to 40 $Kg.ha^{-1}$ of nitrogen.
Pruning	Highly limited to observe the natural behaviour of the trees.
Soil management	Within-row weed control by tillage operations (up to 5 times per year).
Thinning	Adapted to vigour and fruit load (manual thinning).
Pests and diseases management	*Scab.* Leaf shredding in GOT site. 0 to 6 sulphur or copper treatments during period of high ejection of ascospores. Treatments were stopped when 95% of ascopores were ejected. *Aphids.* 1 to 3 mineral oil applications per year. *Powdery Mildew.* From 0 to 5 sulphur treatments per year. *Codling Moth.* Mating disruption, *Bt* and granulosis virus microbiological insecticides, cardboard traps, preventive treatments during peaks of flight.

Scab (*Venturia inaequalis*), aphids (*Dysaphis plantaginea*, *Aphis pomi* and *Dysaphis anthrisci*) and powdery mildew (*Podosphaera leucotricha*) damages were observed monthly from April to July on leaves. The intensity of damages was ranked in 5 classes (Table 2). The results presented in this paper are based on the analysis of the 2003-2006 period in the four sites.

Table 2: Severity scale for the assessment of scab, aphids and powdery mildew symptoms observed on leaves.

Scale	Scab	Aphids / Powdery Mildew
1	No visible symptom	No aphid / No powdery mildew
2	Few spots observed in limited locations	1 -10% infested shoots
3	Spots immediately visible and located in the whole crown	11 - 25% infested shoots
5	At least one spot on 80% of the leaves	26 - 50% infested shoots
7	More than 50 % of leaf area covered by scab	51 - 75% infested shoots
9	Almost all the leaves covered by scab	75 - 100% infested shoots

Alternate bearing was quantified by the difference between the maximum and the minimum yield observed divided by the mean yield. Five classes of yield and alternate bearing were distinguished. A value of 1 was attributed to high yield and cultivars with regular yield.

Results

<u>Susceptibility to scab</u>

Because rootstock effect on scab susceptibility was not significant, rootstocks were pooled per cultivar for analysis. *Vf*-resistant cultivars displayed no scab symptoms in GOT, GRA and CIR sites. In the GAB site (Figure 2), the 11 *Vf*-resistant cultivars displayed different levels of scab severity. In this latter site, symptoms were first detected in 2005, except for Florina cultivar. Six levels of scab severity can be distinguished on the basis of statistical analysis (Bonferroni test, $\alpha = 0.05$, data not shown).

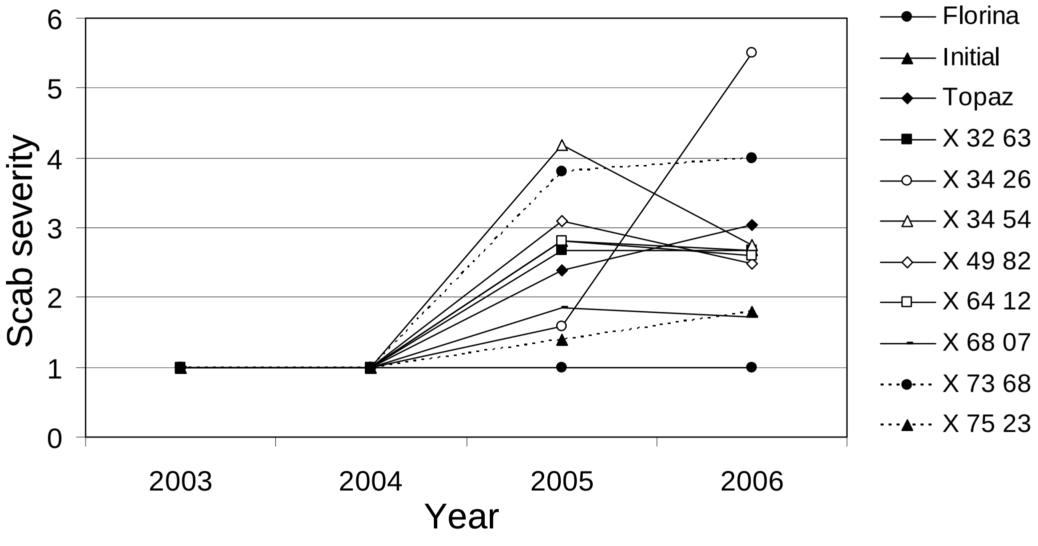


Figure 2: Mean scab severity scores of 11 *Vf* cultivars in the GAB site. Sample size for X7368 and X7523 is *n*=5; for the other cultivars it ranges from 16 to 23. X6412 line is printed over Initial line.

Concerning the cultivars without *Vf* gene, different levels of scab severity were observed according to the site and cultivar. Mustu (selected as a highly susceptible control) is the most susceptible cultivar. On the opposite, no symptom was observed on Reinette de Champagne cultivar in CIR, GOT and GRA sites. Eight cultivars did not display any symptom in GOT and GRA sites, but three of them (Cabarette, Reinette de Capucins and Pinova) showed low to intermediate levels of scab damages in the GAB site. X7409 cultivar displayed different levels of scab damages according to the site. This attests to differences in disease pressure between the four sites.

Table 3: Scab susceptibility of 13 non *Vf* cultivars in the four sites. Values are the maximum mean severity scores with standard deviation observed between 2003 and 2006 for each cultivar and each site.

Cultivars	**CIR**	**GOT**	**GRA**	**GAB**
Cabarette	-	1.0 ± 0.0	1.0 ± 0.0	3.2 ±0.8
Reinette des Capucins	-	1.0 ± 0.0	1.0 ± 0.0	2.5 ±0.9
Provençale Rouge d'Hiver	-	1.0 ± 0.0	1.0 ± 0.0	-
Pomme d'Adam	-	-	1.0 ± 0.0	-
Pomme de Risoul	-	-	1.0 ± 0.0	-
De l'Estre	-	1.0 ± 0.0	-	-
Court Pendu Gris du Limousin	-	1.0 ± 0.0	1.0 ± 0.0	-
Azéroli Anisée	-	1.9 ± 0.4	1.25 ± 0.5	-
Mutsu	-	5.0 ± 0.0	5.6 ±0.5	-
Coquette	3.4±0.9	2.0 ± 0.0	2.5 ±0.7	-
Reinette de Champagne	1.0 ± 0.0	1.0 ± 0.0	1.0 ± 0.0	-
X7409	4.9±1.6	1.5 ± 0.5	1.3 ±0.5	6.71 ±0.5
Pinova	-	1.0 ± 0.0	1.0 ± 0.0	5.0 ±0.0

Susceptibility to *Dysaphis plantaginea* aphid

Because rootstock has a significant effect on aphid susceptibility in several cases, this factor has been considered in the data analysis (Table 4). Susceptibility to *A. pomi* and *D. anthrisci* has been assessed but results are not presented.

A high variability in the susceptibility to *D. plantaginea* was observed in GOT and GRA sites whereas the variability of the susceptibility was lower in CIR and GAB sites. In GOT site, aphid susceptibility on M7 rootstock ranged from 1.4 for Florina cultivar to 6.4 for Topaz cultivar. A higher pest pressure in GOT and GRA sites could explain this result. In CIR site, the intensity of damages was low because the pest pressure was limited. An effect of the rootstock on *D. plantaginea* susceptibility could be observed in several cases but differences are seldom significant. No trend could be identified between the level of susceptibility and the type of cultivar (old cultivars and recent hybrid).

Table 4: Susceptibility to *Dysaphis plantaginea* of 36 cultivars in the four sites. Values are the maximum mean severity scores with standard deviation observed between 2003 and 2006. The number of trees observed ranged from n = 5 to 10 and from n = 5 to 18 for M7 and PI80 rootstocks, respectively.

	M7 rootstock				**PI80 rootstock**			
Cultivars	**CIR**	**GOT**	**GRA**	**GAB**	**CIR**	**GOT**	**GRA**	**GAB**
Azéroli anisé	-	3.0±1.5	-	-	-	2±0.8	-	-
Cabarette	-	2.4±0.5	2.8±1.5	2.1±2.5[1]	-	-	2.2±1.7	-
Coquette	1.0±0.0	2.8±0.4	-	-	-	-	-	-
Court Pendu[2]	-	6.2±2.6	4.0±2.5	-	-	-	1.3±0.5	-
De l'Estre	-	2.2±0.9	-	-	-	1.4±0.6	-	-
DL13	1.4±0.5	-	3.6±1.1	-	-	-	5.2±2.0	-
DL32	1.0±0.0	-	4.2±2.2	-	-	-	2.6±0.5	-
DL41	1.2±0.4	-	4.0±1.8	-	-	-	3.2±0.8	-
DL44	1.2±0.4	-	2.6±1.3	-	-	-	2.8±0.8	-
DL48	1.2±0.4	-	3.6±1.1	-	-	-	5.0±2.7	-
Florina	1.0±0.0	1.4±0.5	1.1±0.3	1.0±0.0[3]	1.0±0.0	1.2±0.4	1.2±0.7	1.0±0.2
Initial	1.1±0.3	4.8±1.8	2.4±0.8	1.0±0.0[3]	1.3±1.0	5.9±3.4	-	1.7±2.0
Mutsu	-	-	2.6±0.8	-	-	-	-	-
Pinova	-	-	1.4±0.5	2.0±2.6[3]	-	-	-	1.1±0.5
Pitchounette	-	-	-	-	-	2.4±0.8	1.4±0.7	-
P. d'Adam[4]	-	-	4.0±0.7	-	-	-	-	-
Provençale[5]	-	4.5±2.9	-	-	-	4.6±2.4	2.4±1.8	-
R. de Champ[6]	-	4.6±1.6	1.4±0.8	-	-	-	-	-
R. des Cap[7]	-	3.1±2.9	1.8±0.9	1.1±0.4[3]	-	3.5±2.0	-	-
René Vert	1.0±0.0	-	-	-	1.0±0.0	-	-	-
Risoul	-	-	2.4±1.9	-	-	-	-	-
Topaz	1.2±0.4	6.4±3.2	2.1±1.3	2.0±2.6[3]	2.0±1.8	4.8±3.4	2.6±1.9	4.5±2.9
X3263	-	4.2±1.0	2.2±1.7	1.0±0.0[3]	-	-	-	1.1±0.5
X3426	1.0±0.0	-	1.8±0.4	1.5±1.2[3]	1.2±0.5	-	-	1.2±0.8
X3454	1.1±0.3	-	3.3±1.7	-	2.2±1.3	3.5±2.5	-	3.8±2.8
X3460	1.4±0.5	-	2.5±1.1	-	1.4±1.0	3.0±0.0	-	-
X4982	1.0±0.0	-	1.0±0.0	1.0±0.0[3]	-	-	-	1.0±0.0
X6398	-	3.8±1.7	-	-	-	-	-	-
X6407	-	5.8±2.6	-	-	-	-	-	-
X6412	1.0±0.0	5.4±1.6	3.4±1.5	1.7±1.8[3]	-	-	-	2.2±2.4
X6688	-	-	-	-	2.0±2.1	5.2±1.6	-	-
X6807	1.8±0.7	3.1±1.9	4.2±1.1	-	2.3±1.8	2.1±1.1	2.1±1.0	1.4±1.6
X7362	1.0±0.0	-	-	-	-	-	-	-
X7368	-	1.2±0.4	1.2±0.4	-	-	-	-	-
X7409	1.8±0.7	8.4±0.9	5.5±1.8	1.1±1.3[3]	2.3±1.8	5.8±2.9	3.7±2.5	-
X7523	1.0±0.0	1.4±0.8	1.0±0.0	-	-	-	-	-

[1]: M7 own-rooted trees; [2]: Court Pendu Gris du Limousin; [3]: M106 rootstock; [4]: Pomme d’Adam ; [5]:Provençale Rouge d’Hiver; [6]: Reinette de Champagne ; [7]: Reinette des Capucins

Susceptibility to powdery mildew

Rootstock effect has been considered in the data analysis. The following cultivars have a maximum mean severity score observed between 2003 and 2006 over 2.0 : X4982, DL48, X3460, DL44, DL 41 X3454 and DL13 in CIR site; Topaz and Florina in GOT site; X4982, DL32, X6407, DL44, Reinette des Capucins, DL48 and Goldrush in GRA site and X4982 in

GAB site. The highest susceptibility to powdery mildew was observed on CIR and GRA sites. In GOT and GAB sites, powdery mildew was not a serious problem because mildew control was sufficient. X4982 was the most susceptible cultivar on the three sites where it was assessed.

Discussion

The overcome of *Vf* resistance observed in the GAB site is consistent with the spatial distribution of strains able to breakdown the *Vf*-gene (Didelot *et al*., 2009): in the North of France, the occurence of these strains is higher than in the Southern part. Because such overcoming process seems unavoidable, the assessment of the susceptibility of *Vf*-cultivars in such conditions provides valuable information. However, the level of susceptibility can vary in space and time. For example, the *Vf* resistance of Florina cultivar has been overcome in another study site (Brun, pers. com.).

Exhaustive studies of susceptibility to aphid are scarse. Angeli & Simoni (2006) and Arnaoudov & Kutinkova (2006) have shown that Florina is the most tolerant cultivar within their cultivar range, which is consistent with our results. This database could provide relevant information to identify tolerant cultivars in a breeding selection process.

This study has permitted to identify cultivars of poor interest in organic production: DL44, DL 41 and X3426 have a poor taste quality, X6688 is highly susceptible to *D. plantaginea*; Court Pendu Gris du Limousin has an erected habit and a high susceptibility to *D. plantaginea* on M7 rootstock.

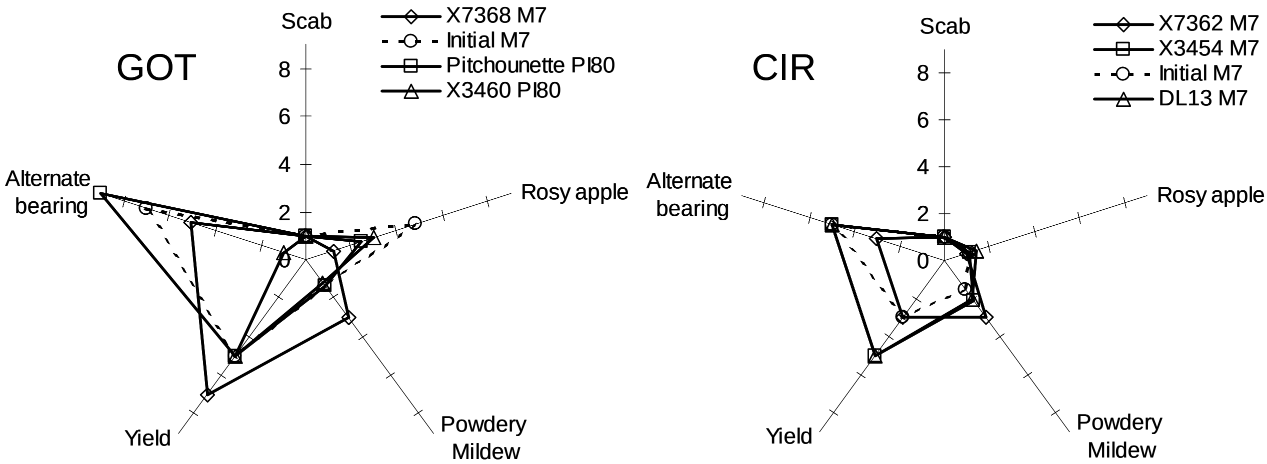


Figure 3: Mean maximum severity and mean assessment scores for scab, *D. plantaginea*, powdery mildew, yield and alternate bearing of the four most interesting cultivars in GOT and CIR sites. The mean yield was calculated from 2006 to 2009 (GOT) and from 2006 to 2008 (CIR).

On the other hand, some cultivars with interesting agronomical properties, *i.e.* a mix of low susceptibility to pests and diseases and a satisfying level of yield, have been pointed out. In GOT and CIR sites (Figure 3), four cultivars could be identified. In GOT site, Pitchounette showed an interesting compromise although alternate bearing could be a drawback. X3460 exhibited a very interesting pattern in this site. However, because of the weeping natural bearing of this cultivar, thinning is time consuming and has to be considered. In CIR site, X3454 proposed a well-balanced pattern. However, this cultivar showed an intermediate to high level of scab susceptibility in areas where *Vf* resistance is overcome (Figure 2). This suggests that scab control methods should be realized as a prevention or delay of *Vf* gene breakdown (Trapman, 2006; Gomez *et al*., 2007).

Pedoclimatic conditions and pest and disease pressure may vary according to the site and throughout time. Because these parameters influence the cultivar response, an experimental design including several sites to assess cultivars in different climatic and biotic conditions is highly relevant. The differences in pest and disease susceptibility observed between sites and their variability during the 2003-2006 period (datas not shown) underline the interest of such a multilocal approach. It also highlights the difficulty to identify cultivars which have both required low susceptibilities and agronomic properties: among the 36 cultivars initially selected, only a few ones (*e.g.* Figure 3) were identified to be of interest for organic orchard production.

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References

Angeli, G. & Simoni, S. (2006). Apple cultivars acceptance by *Dysaphis plantaginea* Passerini (Homoptera; Aphididae). *Journal of Pest Science* **79(3)**: 175-179.

Arnaoudov, V. & Kutinkova, H. (2006). Susceptibility of some apple cultivars to infestation by rosy apple aphid (*Dysaphis plantaginea* PASS., Homoptera: Aphididae). *Journal of Fruit and Ornemental Plant Research* **14(3)**: 137-142.

Didelot, F., Parisi, L., Orain, G., Lemarquand, A., Le Cam, B., Laurens, F. & Caffier, V. (2009). Situation actuelle en France du contournement de la résistance *Vf* par *Venturia inaequalis* – Propositions de méthodes de lutte adaptées. Journée technique Fruits et Légumes ITAB-GRAB, 8-9 December, 2009, Paris, France, pp. 65-68.

Gomez C., Libourel G., Romet L., Warlop F., Brun L., Simon S., Pouzoulet D., Delebecq A., Laurens F., Oste S. & Tournant L. (2006). « Semi-extensive » orchards as a model for sustainable fruit growing. 12th International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit-Growing, Weinsberg, Germany.

Gomez C., Brun L., Chauffour D., De Le Vallée, D. (2007). Effect of leaf litter management on scab development in an organic apple orchard. *Agriculture, Ecosystems and Environment* **118**: 249–255.

Trapman, M. (2006). Resistance management in Vf resistant organic apple orchards. *IOBC wprs Bulletin* **29**: 253-257.

Trapman, M. & Jansonius P.J. (2008). Disease management in organic apple orchards is more than applying the right product at the correct time. 13th International Conference on Organic Fruit Growing, Weinsberg, Germany.