PROJECT TITLE

Developing Apple Pest control strategies through an Integrated agro-ecosystem approach

TOPIC

Topic A2: Integrated, sustainable and resilient Cropping systems (RESCROPS)

YOUR PROJECT IS RELATED TO

Topic B1: Innovative direct biological control methods in holistic IPM approach (INDIBICOM-IPM)

PROJECT DURATION	TOTAL REQUESTED FUNDING	TOTAL COSTS
36 Months	812.627 €	978.979 €

CONSORTIUM

P 1	Dr Aude Alaphilippe Institut national de la recherche agronomique	460, Domaine de Gotheron, 26320 ST-Marcel-Lès-Valence France	savage@paca.inra.fr Tel.: 0033 4 75 59 92 00 Fax: 0033 4 75 58 86 26 https://www.inra.fr
P 2	Prof Lene Sigsgaard University of Copenhagen	Thorvaldsensvej 40, 1871 Frederiksberg C Denmark	les@plen.ku.dk Tel.: 0045 35332674 Mobile: 0045 21151827 http://www.plen.ku.dk
P 3	Dr Claude-Eric Parveaud GRAB Research Group for Organic Farming	Domaine de Gotheron, 26320 Saint Marcel les Valence France	claudeeric.parveaud@grab.fr Tel.: 0033 475599208 Mobile: 0033 681374582 http://www.grab.fr
P 4	Prof Thierry Hance Université catholique de Louvain	Croix du SUD, 4-5, L7.07.04, 1348 Louvain-la-Neuve Belgium (Flanders and Wallonia)	thierry.hance@uclouvain.be Tel.: 0032 010473493 Fax: 0032 010473490 http://www.uclouvain.be/index.html
P 5	Prof Marco Tasin Swedish University of Agricultural Science	Växtskyddsvägen 3, 102, 23053 Alnarp Sweden	marco.tasin@slu.se Tel.: 0046 40415320 Mobile: 0046 762368786 http://www.slu.se
P 6	Dr Marc Lateur CENTRE WALLON de RECHERCHES AGRONOMIQUES	Bâtiment Emile Marchal, Rue de Liroux, 4, 5030 GEMBLOUX Belgium (Flanders and Wallonia)	m.lateur@cra.wallonie.be Tel.: 0032 81620333 Fax: 0032 81620349 http://www.cra.wallonie.be/fr
P 7	Dr Georgina Alins Institut de Recerca i Tecnologia Agroalimentaries	Parc Científic i Tecnològic Agroalimentari de Lleida, 25003 Lleida Spain	Georgina.Alins@irta.cat Tel.: 0034 973 032 850 http://www.irta.cat
P 8	Dr Enrique Dapena Servicio Regional de Investigación y Desarrollo Agroalimentario	Ctra. de Oviedo, sn, Apdo. 13, 33300 Villaviciosa Spain	edapena@serida.org Tel.: 0034 985890066 Mobile: 0034 678533796 Fax: 0034 985891854 http://www.serida.org

KEYWORDS

Pre-defined keywords	Integrated, sustainable, resilient, systems, pests
Supplementary keywords	orchard system, natural enemies, habitat management, plant diversity, co-design

PARTNER DATA

Partner 1 (Consortium Coordinator): Institut national de la recherche agronomique

FINANCE COMMENTS

Personnel	Non permanent staff -Technical assistance for field work, 7 p.month -Assistant for evaluation & coordination, 16.5 p.month Master2 degree trainees, 4 x 6 months & technical trainees
Travel	Travel expenses Meetings, workshops, congress participation, field trips, 24k€/15 permanent staff
Consumables / Equipment	Experimental orchard inputs & management 13.5k€, experimental costs 20 k€ for monitoring, lab and data analysis (included 4k€ molecular biology & 3k€ biochemical analyses); desk expenses for non permanent staff 2k€, meeting organisation (as coordinator) 1k€; publication costs 0.5k€
Subcontracts	Expertises 1k€ (multicriteria assessment), laboratory analyses (plant samples) & insect identification 3k€
Other	

TASK(S)

INRA coordinates the project, having long-term collaborations with most of the project partners. The three INRA teams will contribute to design and implement resilient apple orchards with focus on push/pull plant assemblages, optimized tree nutrition, conservation of natural enemies and release of parasitoids. Contribution also includes analyses of tree nutrient status and plant volatiles emissions, pest predation assessment and ant diversion. INRA leads the task WP4 on multicriteria assessment.

LITERATURE REFERENCES

- Alaphilippe A., Boissy J., Simon S., Godard C.
  Environmental impact of intensive versus semi-extensive apple orchards: use of a specific methodological framework for Life Cycle Assessments (LCA) in perennial crops
  Journal of Cleaner Production (127), 555-561 (2016)
  DOI: 10.1016/j.jclepro.2016.04.031
- Alaphilippe A., Elad Y., Rav david D., Derridj S., Gessler C.
  Effects of a biocontrol agent of apple powdery mildew (Podosphaera leucotricha) on the host plant and on non-target organisms: an insect pest (Cydia pomonella) and a pathogen (Venturia inaequalis).
  Biocontrol Science and Technology (18(1-2)), 121-138 (2008)
  DOI: 10.1080/09583150701818964
- Boreau de Roince, C., Lavigne, C., Mandrin, J. F., Rollard, C. and Symondson, W. O. C.
  Early-season predation on aphids by winter-active spiders in apple orchards revealed by diagnostic PCR
  Bulletin of Entomological Research (103), 148-154 (2013)
- Dib, H., Simon, S., Sauphanor, B. Capowiez, Y.
  The role of natural enemies on the population dynamics of the rosy apple aphid, Dysaphis plantaginea Passerini (Hemiptera: Aphididae) in organic apple orchards in south-eastern France.
  Biological Control (55), 97-109 (2010)
  DOI: 10.1016/j.biocontrol.2010.07.005
- Maalouly M, Franck P, Bouvier J-C, Toubon J-F, Lavigne C.
  Codling moth parasitism is affected by semi-natural habitats and agricultural practices at orchard and landscape levels.
  Agriculture, Ecosystems & Environment (169), 33-42 (2013)
  DOI: 10.1016/j.agee.2013.02.008
- Sauge MH, Grechi I, Poëssel JL
  Nitrogen fertilization effects on Myzus persicae aphid dynamics on peach: vegetative growth allocation or defensive chemistry effects?
  Entomologia Experimentalis et Applicata (136), 123-133 (2010)
  DOI: 10.1111/j.1570-7458.2010.01008.x
- Ben Issa R, Gautier H, Gomez L
  Which companion plants can affect the performance of green peach aphid on host plants? Screening of thirteen candidate plants under laboratory conditions
  Entomogia Experimentalis et Applicata (in press) (), (2016)
- Simon S., Morel K., Durand E., Brevalle G., Girard T., Lauri PE.
  Aphids at crossroads: when branch architecture alters aphid infestation patterns in the apple tree.
  Trees Structure and Function (26), 273-282 (2012)

DOI: 10.1007/s00468-011-0629-8
- Veres A, Petit S, Conord C, Lavigne C.
  Does landscape composition affect pest abundance and their control by natural enemies? A review.
  Agriculture, Ecosystems & Environment (166), 110-117 (2011)
  DOI: 10.1016/j.agee.2011.05.027
- Zboralski A., Vilarelle M., Colombel E., Tabone E., Vercken E.
  Density-dependent dispersal in biological control agents: a reflexion on the side-effects of mass-rearing conditions.
  Biocontrol (31(1)), 13-22 (2016)
  DOI: 10.1007/s10526-015-9696-x

ADDITIONAL FIELDS

Organisation acronym	INRA
Funding agency	MAAF

Partner 2: University of Copenhagen

FINANCE COMMENTS

Personnel	-Technical assistance for field & lab work, 2 p.month (+1.5 co-financed) -Post doc 12 p.month -Senior scientist: research and general coordination, 2 p.month (+2 cofinanced)
Travel	Travel expenses Meetings, workshops, congress participation, 4k€
Consumables / Equipment	Experimental orchard inputs, lab equipment, desk costs for non-permanent staff 18k€
Subcontracts	
Other	

TASK(S)

UCPH will lead WP3 on identifying levers for which not enough knowledge is yet available, and our main contribution will be towards this task but we will also contribute to the other three cross cutting tasks to develop resilient IPM management in apple orchards. Experimentally, we will particularly focus on top down processes and direct measures against the aphid complex and the codling moth.

LITERATURE REFERENCES

- Kabi, S., Karungi, J., Sigsgaard, L. and Ssebuliba, J.M.
  Dysmicoccus brevipes (Cockerell) occurrence and infestation behaviour as influenced by farm type, cropping systems and soil management practices
  Agriculture, Ecosystems & Environment (222), 23-29 (2016)
  http://www.sciencedirect.com/science/article/pii/S0167880916300524/ doi:10.1016/j.agee.2016.01.040
- Jacobsen, S. K., Alexakis, I. Sigsgaard, L.
  Antipredator responses in Tetranychus urticae differ with predator specialization.
  Journal of Applied Entomology (140), 228-231 (2016)
  http://onlinelibrary.wiley.com/doi/10.1111/jen.12275/abstract /doi: 10.1111/jen.12275
- Gacheri, C., Kigen, T., Sigsgaard, L.
  Hot-spot application of biocontrol agents to replace pesticides in large scale commercial rose farms in Kenya.
  BioControl (60), 795-803 (2015)
  http://link.springer.com/article/10.1007%2Fs10526-015-9685-0/ DOI: 10.1007/s10526-015-9685-0
- Sigsgaard, L.
  Conservation biological control of codling moth, Cydia pomonella
  IOBC-WPRS Bulletin (100), 123-126 (2014)
  http://orgprints.org/26459/13/26459a.pdf
- Sigsgaard, L., Haukeland, S., Naulin, C., Kristensen, K., Enkegaard, A., Jensen, NL, Eilenberg J.
  Strawberry cropping practice effects on pests and their natural enemies
  Journal of Insect Science (14:122), (2014)

http://www.bioone.org/doi/pdf/10.1673/031.014.122/ DOI: http://dx.doi.org/10.1673/031.014.122
- Sigsgaard L, Betzer C, Naulin C, Eilenberg J, Enkegaard A, Kristensen K.
  The effect of floral resources on parasitoid and host longevity: Prospects for conservation biological control in strawberries.
  Journal of Insect Science (13:104), 1-17 (2013)
  http://www.bioone.org/doi/abs/10.1673/031.013.10401/ doi: http://dx.doi.org/10.1673/031.013.10401
- Sigsgaard, L.
  Habitat and prey preferences of the two predatory bugs Anthocoris nemorum (L.) and A. nemoralis (Fabricius) (Anthocoridae: Hemiptera-Heteroptera)
  Biological Control (53), 46-54 (2010)
  http://www.sciencedirect.com/science/article/pii/S1049964409002953/ DOI:10.1016/j.biocontrol.2009.11.005
- Sigsgaard, L., Esbjerg, P. and Philipsen, H.
  Experimental releases of Anthocoris nemoralis F. and A. nemorum (L.) (Heteroptera: Anthocoridae) against the pear psyllid Cacopsylla pyri L. (Homoptera: Psyllidae) in pear
  Biological control (39), 87-95 (2006)
  http://www.sciencedirect.com/science/article/pii/S1049964406000582/ doi:10.1016/j.biocontrol.2006.02.008
- Ahrenfeldt, EJ, Klatt, BK, Arildsen, J, Trandem N, Andersson G, Tscharntke T, Smith HG, Sigsgaard, L.
  Pollinator communities in strawberry crops - variation at multiple spatial scales
  Bulletin of Entomological Research (105), 497 - 506 (2015)
  http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=9846724&fileId=S000748531500036X/ DOI: http://dx.doi.org/10.1017/S000748531500036X
- Wibe, A. Borg-Karlson, A.K., Cross, J., Bichão, H., Fountain, M., Liblikas, I., Sigsgaard, L.
  Aggregation pheromones and wild strawberry volatiles (1,4-Dimethoxybenzene and Germacrene-D) in the attraction of strawberry blossom weevil (Anthonomus rubi)
  Crop Protection (64), 122-128 (2014)
  http://www.sciencedirect.com/science/article/pii/S0261219414002014/ doi:10.1016/j.cropro.2014.06.016

ADDITIONAL FIELDS

Organisation acronym	UCPH
Funding agency	DAFA

Partner 3: GRAB Research Group for Organic Farming

FINANCE COMMENTS

Personnel	-Junior scientists, permanent staff 9 p.month -Trainees, 2 x 3 months
Travel	Travel expenses Meetings, workshops, congress participation, field trips, 4k€
Consumables / Equipment	Experimental orchard inputs and sampling devices (essential oil, emergence traps) 4k€
Subcontracts	Laboratory analyses and insect identification 2k€
Other	

TASK(S)

GRAB will be involved in the setting-up of on-station and on-farm trials in organic orchards. GRAB will contribute to assess (1) the potential interest of volatiles emitted by essential oils and (2) combined cultural practices to discourage pests development. Pests threatening organic apple production will be preferably targeted. GRAB will harness his expertise through the implementation of organic fruit researches adapted to commercial farms conditions.

LITERATURE REFERENCES

- Parveaud C.E., Brenner, J, Libourel G., Albert L., Guérin A., C., Mercier V.
  Verger Bas Intrants : La biodiversité fonctionnelle pour réduire les intrants phytosanitaires
  Réussir Fruits & Légumes (342), 12 (2014)
- Parisi L., Gros C., Combe F., Parveaud C.E., Gomez C., Brun L.

Impact of a cultivar mixture on scab, powdery mildew and rosy aphid in an organic apple orchard
Crop Protection (43), 207-212 (2013)
10.1016/j.cropro.2012.09.014
- Gomez C., Parveaud CE., Libourel G., Romet L., Warlop F., Brun L., Simon S., Pouzoulet D., Delebecq A., Laurens F., Oste S., Tournant L.
Sensibilité variétale aux maladies et ravageurs. Anciennes et nouvelles variétés en AB : Puceron cendré du pommier
Arboriculture Fruitière (), (2012)
- Dib H., Libourel G., Warlop F.
Entomological and functional role of floral strips in an organic apple orchard: Hymenopteran parasitoids as a case study
Journal of Insect Conservation (16), 315-318 (2012)
10.1007/s10841-012-9471-6

ADDITIONAL FIELDS

Organisation acronym	GRAB
Funding agency	MAAF

Partner 4: Université catholique de Louvain

FINANCE COMMENTS

Personnel	Non permanent staff -Junior scientist for field & lab work, 10 p.month -Senior Scientist for coordination 0.7 p.month
Travel	Travel expenses Meetings, workshops, congress participation, 3 k€
Consumables / Equipment	Sampling devices, insect for mass release, consumables and experimental costs 3.5 k€
Subcontracts	
Other	

TASK(S)

UCLouvain will lead WP1 on sharing protocols and data. In collaboration with Dr. Lateur (CRA-W), we will combine cover crops and flower strips to favour natural enemies and to perform mass release of two parasitoids (A. matricariae and E. cerasicola) and one predator (A. aphidimyza) to control D. plantaginea. Indeed, nectar and pollen provision will avoid dispersal of the released individuals and should improve their development in the orchard. The other insect pests will be also monitored.

LITERATURE REFERENCES

- Hance T., van Baaren J., Vernon P. , Boivin G.,
Impact of extreme temperatures on parasitoids in a climate change perspective
Annual review of Entomology (52), 107-126 (2007)
52.110405.091333
- Stilmant D, Van Bellinghen C, Hance T, G. Boivin
Host specialization in habitat specialists and generalists
Oecologia (156), 905-912 (2008)
- Dumont, V.-A., Trigaux, A., Moreau, A., and Hance, T.
Study of two conditioning methods of parasitoids used in biological control prior to inundative releases in apple orchards
European Journal of Environmental Sciences (1), 51-56 (2011)
- Boivin, G., Hance, T., Brodeur, J.
Aphid parasitoids in biological control
Can. J. Plant Sci (92), 1-12 (2012)
- Nicolas, A., Dagbert, T., Le Goff, G., & Hance, T. (2015). La lutte biologique contre le puceron cendré du pommier par des lâchers d'auxiliaires en verger. Earth and Life Insitute, Louvain-la-Neuve, 30 pp
La lutte biologique contre le puceron cendré du pommier par des lâchers d'auxiliaires en verger
Earth and Life Institute, Louvain-la-Neuve (Edts), Louvain-la-Neuve (), 30 (2015)
- Wu, G.-M., Barrette, M., Boivin, G., Brodeur, J., Giraldeau, L.-A., and T. Hance, 2011

Temperature influences the handling efficiency of an aphid parasitoid through body size-mediated effects
Environmental Entomology (40), 737-742 (2011)
- Ismail, M., Van Baaren, J., Hance, T., Pierre, J.-S., Vernon, P.
Stress intensity and fitness in the parasitoid Aphidius ervi (Hymenoptera: Braconidae): temperature below the development threshold combined with a fluctuating thermal regime is a must.
Ecological Entomolog (38(4)), 355-363 (2013)
10.1111/een.12025
- Muratori, F.B., Rouyar, A. and Hance, T.
Clonal variation in aggregation and defensive behavior in pea aphids
Behavioral Ecology, (25(4), 901-908. (2014)
- Jerbi-Elayed, M., Lebdi-Grissa, K., Le Goff, G. and Hance, T., 2015. Influence of Temperature on Flight, Walking and Oviposition Capacities of two Aphid Parasitoid Species (Hymenoptera: Aphidiinae). Journal of Insect Behavior, 28(2), 157-166.
Influence of Temperature on Flight, Walking and Oviposition Capacities of two Aphid Parasitoid Species (Hymenoptera: Aphidiinae)
Journal of Insect Behavior (28(2)), 157-166. (2015)
- Le Goff, G. J., Nicolas, A., Al Mohamad, R., & Hance, T.
Impact of Humidity on the Biological Development of Aphidoletes aphidimyza (Diptera: Cecidomyiidae).
Journal of economic entomology (in Press), (2016)

ADDITIONAL FIELDS

Organisation acronym	ELIB/UCL
Funding agency	SPW-DGO3

Partner 5: Swedish University of Agricultural Science

FINANCE COMMENTS

Personnel	Post-doc fellowship 24 p.month
Travel	Travel expenses Meetings, workshops, field trips, 6k€
Consumables / Equipment	Innovative orchard planting & management 12.5k€; compensation to growers (if damage) 2.5 k€; pest monitoring (traps, semiochemicals, sampling trap) 5k€
Subcontracts	
Other	

TASK(S)

SLU Alnarp (Sweden) will be the leader of WP2 “Design of systems with combinations of levers and orchard co-design”. The designed systems will be based on combinations of levers adapted to local conditions. We aim at combining disruption of ant behavior to enhance biocontrol of aphids with push&pull system to decrease aphid establishment and with trap crop to decrease moths damage.

LITERATURE REFERENCES

- Ondiaka S, Migiro L, Rur M, Birgersson G, Porcel M, Ramert B & Tasin M.
Sunflower as a trap crop for the European tarnished plant bug (Lygus rugulipennis)
Journal of Applied Entomology (), (2015)
DOI: 10.1111/jen.12273
- Knudsen GK and Tasin M.
Spotting the invaders: a monitoring system based on plant volatiles to forecast apple fruit moth attacks in apple orchards
Basic and Applied Ecology (), (2015)
DOI 10.1016/j.baae.2015.03.006
- Sjöberg P, Swiergiel W, Thierfelder T, Tasin M, Rämert B
Pest management strategies against the apple sawfly (Hoplocampa testudinea Klug) adapted to Swedish conditions
Journal of Pest Science (), (2014)
DOI 10.1007/s10340-014-0616-0.

- Porcel M, Sjöberg P, Swiergiel W, Dinwiddie R, Rämert B and Tasin M
  Mating disruption of Spilonota ocellana and other apple orchard tortricids using a multispecies reservoir dispenser
  Pest Management Science (), (2014)
  10.1002/ps.3844
- Kárpáti Z, Tasin M, Cardé RT, Dekker T
  Early quality assessment lessens pheromone specificity in a moth
  Proceedings of the National Academy of Sciences of the United States of America (), (2013)
  10.1073/pnas.1216145110
- Trona F, Anfora G, Balkenius A, Bengtsson M, Tasin M, Knight A, Janz N, Witzgall P, Ignell
  Neural coding merges sex and habitat chemosensory signals in an insect herbivore
  Proceedings of the Royal Society B (), (2013)
- Tasin M, Cappellin L, Biasioli F
  Fast direct injection mass-spectrometric characterization of stimuli for insect electrophysiology by PTR-ToF-MS
  Sensors (12), 4091 (2012)
- Tasin M, Knudsen GK, Pertot I
  Smelling a diseased host: grapevine moth responses to healthy and fungus-infected grapes
  Animal Behaviour (83), 555 (2012)
- Ioriatti C, Anfora G, Tasin M, De Cristofaro A, Witzgall P, Lucchi A
  Chemical Ecology and Management of Lobesia botrana (Lepidoptera: Tortricidae)
  Journal of Economic Entomology (104), 1125 (2011)
- Tasin M, DeMaria D, Ryne C, Cesano A, Galliano A, Anfora G, Ioriatti C and Alma, A.
  Effect of flat anti-hail nets on Cydia pomonella (L.) behaviour in apple orchards
  Entomologia Experimentalis et Applicata (129), 32 (2008)

ADDITIONAL FIELDS

Organisation acronym	SLU
Funding agency	FORMAS

Partner 6: CENTRE WALLON de RECHERCHES AGRONOMIQUES

FINANCE COMMENTS

Personnel	Non permanent staff -Technical assistance for field & lab work, 9 p.month -Senior scientist for coordination, 1.1 p.month
Travel	Travel expenses Meetings, workshops, congress participation, 4 k€
Consumables / Equipment	Experimental orchard inputs 1.5k€, experimental costs for monitoring, lab and data analysis 1k€
Subcontracts	
Other	

TASK(S)

CRA-W will be involved in lever 3- through cultivar screening and selection concerning rosy apple aphid, codling moth and blossom weevil susceptibility; lever 4- by increasing functional biodiversity with local eco-type flower strips concerning rosy apple aphid and finally CRA-W will work on lever 6- by using a monitoring of codling moth fly emergence risk and applying direct measure such as mass trapping of adults with light traps.

LITERATURE REFERENCES

- Wateau K., Tournant L., Jamar L.
  Décoction de Quassia amara et lutte contre l'hoplocampe du pommier (Hoplocampa testudinea Klug).
  Actes des Journées Techniques Nationales Fruits et Légumes Biologiques, ITAB-GRAB, Paris, 8 & 9 décembre 2009 (), 25-30 (2009)
- Bellon S., Fauriel J., Hemptine J.-L., Jamar L., Lauri P.E., Lateur M., Libourel G., Simon S.
  Eco-design and Co-design: application to fruit production in Europe.

The Second Farming Systems Design Symposium, Monterey (USA), August 23 to 26 (), 29-30 (2009)
- Kellerhals M, Szalatnay M, Hunziker K, Duffy B, Nybom H, Ahmadi-Afzadi M, Höfer M, Richter K, Lateur M
  European pome fruit genetic resources evaluated for disease resistance.
  Trees-Structure and Functions (26), 179-189 (2012)
- Parisi, L., Jamar, L., Lateur, M., Laurens, F., Lauri, P.E.
  Adapting apple ideotypes to low-input fruit production agro-ecosystems
  Organic Farming, Prototype for Sustainable Agriculture. (Springer, Doordrecht), 131-148 (2014)
- Wateau K., Tournant L., Jamar L., Oste S.
  Les ravageurs secondaires en verger de production biologique : recherche de nouvelles techniques de lutte contre Hoplocampa testudinea Klug et Anthonomus pomorum Linnaeus
  AFPP - 4ème Conférence Internationale sur les Méthodes Alternatives en Protection des Cultures, 8, 9 & 10 mars (), 535-545 (2011)
- Jamar L., Lateur M., Tournant L., Wateau K., Dewaegeneire P., Oste S., Montignies E., Thiran B., Delebecq A., Fitoussi J.
  Les principales clès du verger bio transfrontalier – Pommes et poires, une approches globale
  Ed. Interreg IV TransBioFruit (), pp. 89 ()

ADDITIONAL FIELDS

Organisation acronym	CRA-W
Funding agency	SPW-DGO3

Partner 7: Institut de Recerca i Tecnologia Agroalimentaries

FINANCE COMMENTS

Personnel	Non permanent staff Technical assistance for field & lab work, 15.25 p.month
Travel	Travel expenses Meetings, workshops, congress participation, field trips, 5k€
Consumables / Equipment	Experimental orchard inputs 3.1 k€, experimental costs for monitoring, lab and data analysis 3k€
Subcontracts	
Other	

TASK(S)

The tasks that IRTA will carry out in this project will be focused on improving the biological control of the rosy apple aphid by: a) the implementation of flower strips and other companion plants, b) the release of natural enemies and, c) the diversion of ants.

LITERATURE REFERENCES

- Lordan J, Alegre S, Blanco R, Sarasua MJ, Alins G
  Aggregation behavior in the European earwig: Response to impregnated shelters.
  Crop Protection (65), 71-76 (2014)
  10.1016/j.cropro.2014.07.005
- Lordan J, S Alegre, G Alins, MJ Sarasua, A Morton, F Garcia del Pino
  Compatibility between Forficula auricularia and entomopathogenic nematodes to be used in pome fruit pest management
  Journal of Applied Entomology (138), 635-643 (2014)
- Lordan J, S Alegre, R Moerkens, M-J Sarasua, G Alins
  Phenology and interspecific association of Forficula auricularia and Forficula pubescens in apple orchards
  Spanish Journal of Agricultural Research (13), (2015)
  10.5424/sjar/2015131-6814
- Lordan J, S Alegre, F Gatius, M-J Sarasua, G Alins
  Woolly apple aphid Eriosoma lanigerum Hausmann ecology and its relationship with climatic variables and natural enemies in Mediterranean areas
  Bulletin of Entomological Research (105), 60-69 (2015)
  10.1017/s0007485314000753

ADDITIONAL FIELDS

Organisation acronym	IRTA
Funding agency	INIA

Partner 8: Servicio Regional de Investigación y Desarrollo Agroalimentario

FINANCE COMMENTS

Personnel	Non permanent staff Technical assistance for field work, 7 p.month
Travel	Travel expenses Meetings, workshops, congress participation, 7k€
Consumables / Equipment	Experimental orchard inputs and costs for monitoring 2k€; nest boxes for birds, sample materials, sample processing 2k€
Subcontracts	Field sampling, laboratory processing of samples and insect identification 16k€
Other	

TASK(S)

The tasks that SERIDA carry out in this project will be focused on improving the biological control of the rosy apple aphid and codling moth by a better knowledge of;
- the effect of cultivars, rootstock and cropping system
- role of landscape, hedges & ground cover on aphid predator and role of birds

LITERATURE REFERENCES

- Pagliarani, G., Dapena, E., Miñarro, M., Denancé, C., Lespinasse, Y., Rat-Morris, E., Troggio, M., Durel, C.E., Tartarini, S.
  Fine mapping of the rosy apple aphid resistance locus Dp-fl on linkage group 8 of the apple cultivar 'Florina'.
  Tree Genetics and Genomes (in press) (), (2016)
  DOI: 10.1007/s11295-016-1015-x
- Rosa-García, R., Miñarro, M.
  Role of floral resources in the conservation of pollinators in cider apple orchards
  Agriculture, Ecosystems and Environment (183), 118-126 (2014)
- Miñarro, M., Prida, E.
  Hedgerows surrounding organic apple orchards in north-west Spain: potential to conserve beneficial insects
  Agricultural and Forest Entomology (15), 382-390 (2013)
- Miñarro, M
  Weed communities in apple orchards under organic and conventional fertilization and tree-row management
  Crop Protection (39), 89-96 (2012)
- Miñarro, M., Fernández-Mata, G., Medina, P
  Role of ants in structuring the aphid community on apple
  Ecological Entomology (35), 206-215 (2010)
- Miñarro, M., Espadaler, X., Melero, V.X., Suárez-Álvarez, V.
  Organic versus conventional management in an apple orchard: effects of fertilization and tree-row management on ground-dwelling predaceous arthropods
  Agricultural and Forest Entomology (11), 133-142 (2009)
- Miñarro, M., Dapena, E.
  Tolerance of some scab-resistant apple cultivars to the rosy apple aphid, Dysaphis plantaginea
  Crop Protection (27), 391-395 (2008)
- Miñarro, M., Dapena, E
  Resistance of apple cultivars to Dysaphis plantaginea (Hemiptera: Aphididae): role of tree phenology in infestation avoidance
  Environmental Entomology (36), 1206-1211 (2007)
- Miñarro, M., Hemptinne, J-L., Dapena, E.
  Colonization of apple orchards by predators of Dysaphis plantaginea: sequential arrival, response to prey abundance and consequences for biological control
  Biocontrol (50 (3)), 403-414 (2005)
- Miñarro, M., Dapena, E.
  Effects of groundcover management on ground beetles (Coleoptera: Carabidae) in an apple orchard

Applied Soil Ecology (23), 111-117 (2003)

ADDITIONAL FIELDS

Organisation acronym	SERIDA
Funding agency	INIA

ABSTRACT

Apple accounts for 35% of European orchards and the sustainability of apple production is questioned since it relies on a heavy use of pesticides. The objective of the API-tree project is to design and assess the efficiency and sustainability of combinations of practices, which are alternative to chemicals to control apple pests. The whole apple pest complex will be considered, with a focus on aphids, for which chemical control solutions are missing due to regulatory pesticide withdrawal. The novelty of this project is the integrated approach that takes into account agroecosystem management, orchard design and practices, as well as economic constraints. A range of geographic and climatic conditions is covered by API-tree thanks to the consortium, which comprises countries from Northern to Mediterranean Europe. This also permits to share various experiences and knowledge to propose innovative context-adapted solutions. API-tree will permit to design and assess new orchard systems in collaboration with end-users (mainly growers), who will participate in co-design activities and test some proposed strategies in their commercial orchards. Targeted practices will aim at building consistent and resilient systems that reduce both pest attacks and damage to attacked plants. All the partners have skills in ecology and agronomy and expertise in methods and practices that foster the defense of the apple tree against pest attacks and the control of apple pests by their natural enemies. Those practices are related to the enhancement of plant diversity (additional cultivars, cover crops, introduction of companion plants...), to soil and tree management (cultural practices) and to the design of agroecological infrastructures (e.g. habitat management to provide pest natural enemies with food resources and shelters, push-pull plant assemblages etc.). The sustainability of the designed strategies will be evaluated using the multicriteria assessment tool DEXiFruits to account for economic, environmental and social performances of the experimented orchards. The outcomes of the project are i) Integrated Pest Management strategies which can be implemented in different contexts, with information on their efficacy, mode of action, feasibility and costs; ii) methods to design and evaluate innovative orchards and iii) knowledge sharing and dissemination, including European and local interactions to discuss and implement approaches and orchard systems with advisors and growers.

BACKGROUND

Apple tree (*Malus* × *domestica* Borkh.) is the most common fruit tree that represents 450,000 ha in Europe and 35% of the total orchard surface area (Eurostat, 2014). Current orchards also rely on a heavy use of pesticides (MAAF, 2012). The risk of environmental contamination is high and apples with pesticide residues are a concern for consumers. The sustainability of apple orchards is therefore questioned. However, the control of insect pests such as codling moth (*Cydia pomonella*) and aphids (mainly the rosy apple aphid *Dysaphis plantaginea*) is critical for apple production. The woolly apple aphid (*Eriosoma lanigerum*), the oriental fruit moth (*Grapholita molesta*), the apple blossom weevil (*Anthonomus pomorum*), the European apple sawfly (*Hoplocampa testudinea*) and tortricid leafrollers can also cause severe or even total fruit losses according to countries or cropping practices. Moreover, the conventional control of aphids mainly relies on neonicotinoid compounds which are under scrutiny. Both economic and ecological outcomes are therefore challenging.

Integrated pest management (IPM) has developed since the 1970s in Europe (Baggiolini et al 1973) to answer such challenge. More recently, alternative methods to chemicals were made available to growers (e.g. mating disruption) but they targeted single pests and/or lacked an overall evaluation of their advantages and limits (Heijne et al 2015). Till now, opportunities to develop interdisciplinary approaches of pest control have been scarce (Lauri et al 2016). There is a need to develop more global approaches to design innovative orchards and decrease such pesticide reliance (Zehnder et al 2007) but systemic approaches are poorly documented in orchards (Simon et al 2016). Some authors (Brown 1999; Malézieux 2012; Ratnadass et al 2012) proposed new insights for the design of agroecological cropping systems (i.e. relying on ecology-based processes rather than external inputs), but such an approach requires further knowledge. There is a need to gather skills, experiences and knowledge from researchers and other stakeholders (e.g. growers, advisors) in various regions and contexts to account for the complexity of agroecosystems such as orchards and consider within-space and –time interactions (Le Bellec et al 2012).

Designing a 'pest suppressive' agroecosystem (i.e. that favors pest suppression) requires i) to avoid the spatio-temporal coincidence of pests and pest-susceptible tree organs ii) to foster both plant-mediated (bottom up) and natural enemy-mediated (top down) processes and iii) to avoid practices hindering targeted processes, namely pesticide use, through the implementation of soft biocontrol solutions. We here propose a general framework based on recent knowledge on ecological processes applied to agroecosystemsto integrate various 'levers' or means of action against pests (Fig. 1), which are mainly related to the enhancement of plant diversity and orchard spatial design.

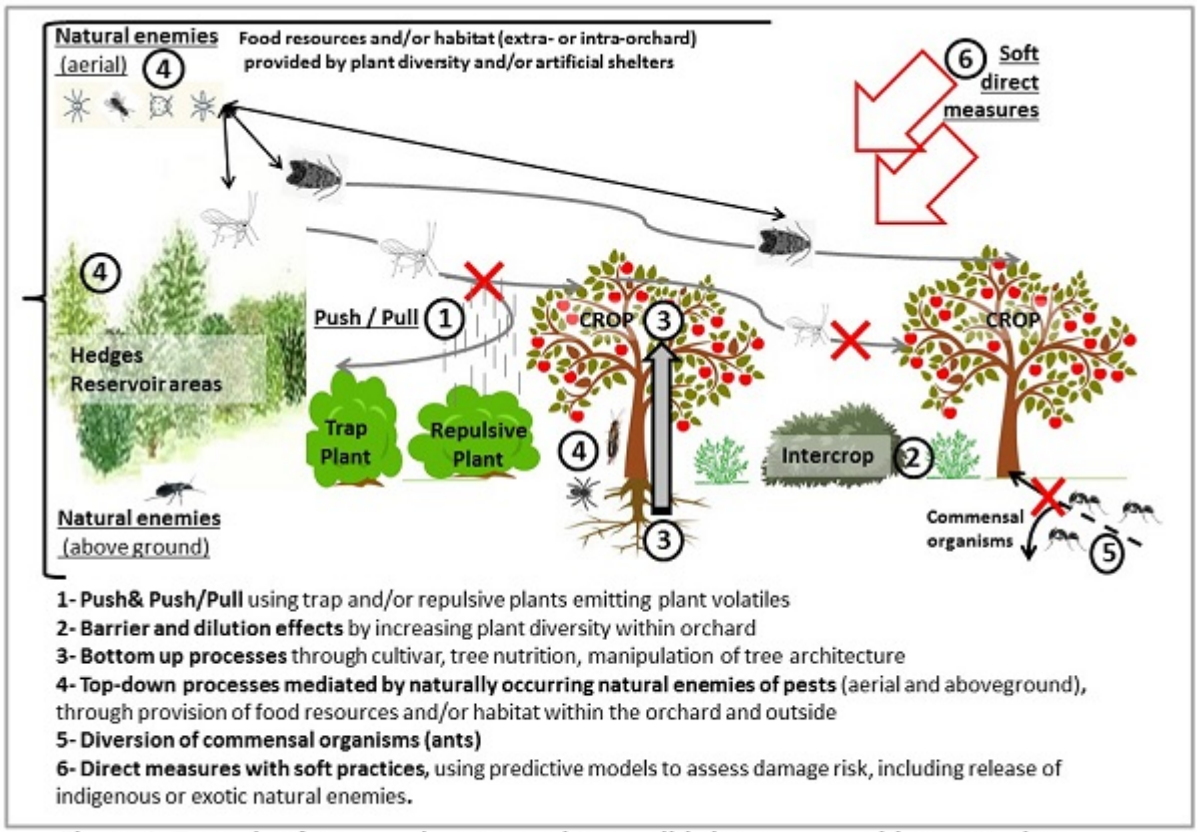


Figure 1. Tentative framework representing possible levers to combine towards a sustainable control of apple pests

Levers 1&2

Pests' foraging activity to localize their host plant is more complex in diversified agroecosystems (Gurr et al 1998) and such diversity also benefits natural enemies of pests (Lever 4; Parolin et al. 2012). Interesting functional traits of apple companion plants are low content of

defence compounds (e.g. susceptible cultivars planted as trap plants around the orchard), emission of plant volatiles disrupting host plant's recognition by aphids (Pickett et al 1992) or affecting aphid behaviour, fecundity and mortality (Amarawardana et al 2007; Ben Issa et al 2016). The diffusion of essential oils as repulsive or disruptive volatile compounds is also a promising approach still to be investigated, e.g. *Achillea millefolium* essential oil sprayed at bloom against sawfly (De Almeida 2012).

Lever 3

Pest damage can also be modulated by cultivar choice: differences in pest susceptibility of apple cultivars have been displayed for the rosy apple aphid (Miñarro & Dapena 2007; Pagliarani et al 2016) or the blossom weevil (Mody et al 2015; Knuff et al 2016). Pests are also affected by cultural practices through modification of the nutrient status of the tree or manipulation of its architecture (Breda et al 2006; Jordan et al 2014). Aphids are particularly receptive to shoot density (Grechi et al 2008), tree branching patterns (Simon et al 2012) and nutrient profile of the host, i.e. C and N organ concentration and composition. However, the effect of N leaf content on aphid performance is controversial (Matis et al 2008; Sauge et al 2010; Mace & Mills 2015). Target leaf N concentrations for aphid resistance optimization as well as the relationship between tree vigour and the success of the return flight of dioecic aphids are still to be investigated in apple.

Lever 4

Both aerial and aboveground natural enemies of pests (NE) support the ecosystem service of pest suppression. The provision of food resources and shelters permitted by habitat conservation at both orchard and farm scales favours NE abundance, diversity and/or efficacy and therefore pest suppression (Landis et al 2000). Agroecological infrastructures include flower strips and other cover crops, hedges, selected non-cultivated habitats, but artificial nesting can also contribute. NE biology (diet, dispersal, lifecycle, life history traits) is here important to consider. Generalist predatory arthropods such as spiders are able to feed on a large range of prey and stay in crops when pest numbers are low, notably early in the season (Symondson et al 2002; Sigsgaard 2010; Boreau de Roincé et al 2013). This prevents pest outbreaks before specialist NE are abundant (Miñarro et al 2005; Dib et al 2010). However, whereasa subsequent increase in NE abundance and/or diversity after plant diversification is well documented, pest suppression is not always observed (Letourneau et al 2009; Simon et al 2010). Interactions among NE are complex (e.g. competition) and multitrophic effects are to be considered (e.g. hyperparasitism). It is therefore important to consider both the presence and the functional role of NE, which can be estimated using sentinel preys (e.g. Ostman 2004) or molecular gut content analysis of field-sampled predators (Boreau de Roincé et al 2012).

Lever 5 & direct methods (6)

Beside trophic interactions, non-trophic interactions related to commensal ants also deserve consideration (Stewart-Jones et al 2004; Miñarro et al 2010). Non-pesticide control methods such as NE release also contribute to successfully control the whole pest complex. Among aphid antagonists, three functional groups have complementary effects: predatory generalists such as earwigs (*Forficula auricularia*) that show great predation potential (Lordan et al 2015; Dib et al 2016); predatory specialists such as ladybirds; and parasitoid wasps, e.g. *Aphidius matricariae* and *Ephedrus cerasicola* on *D. plantaginea* (Dumont et al 2011). Parasitism rates of codling moth by native parasitoids remain low in commercial orchards (less than 5%, Maalouly et al 2013) and are limited by hyperparasitism in absence of pesticide (up to 50%, Maalouly et al 2015). The parasitoid *Mastrus ridens*, native from Central Asia (Kuhlmann & Mills 1999) and successfully introduced in several countries (Mills 2005; Veres et al 2013; Borowiec et al 2016), seems to be an excellent candidate for codling moth biocontrol in France. The impact of this species on the native parasitoid complex and the success of the introduction (species dispersal and efficiency) with regards to landscape features remain to be studied.

Finally, developing an ecosystemic approach of pest control in various regions of Europe could be permitted by i) sharing expertise and knowledge between researchers and stakeholders; ii) considering synergistic effects between a range of levers; iii) developing generic methods to design pest suppressive orchards and iv) providing growers with documented means of action according to specific context and objectives.

WORK PLAN AND WORK PACKAGES

The aim of this project is to develop an integrated agroecological approach of pest control in apple orchards and to explore collectively perspectives in that objective. Innovative design and the sustainability assessment of control method combinations in a range of climatic conditions are the basis of our approach. A range of levers increasing the orchard system resilience to insect pests (Fig 1) will be considered as well as interactions between them. Plant diversity, soil management and orchard design will be considered and complemented by classical biocontrol as non-chemical control method.

We will address the whole insect pest complex of apple orchards in Europe to work on various pest models including sap feeders (aphids), flower feeders (sawfly, blossom weevil) and fruit borers (codling moth and other tortricids), and various NE types including generalist and specialist, predatory and parasitoid NE. A special focus will be set on aphids since it is one major apple tree pest. Moreover, environmentally unfriendly chemical pesticides are generally used to control them.

Innovative design will rely on the integration of research results, experience sharing to identify promising solutions and possible synergistic effects among those solutions, experiments on the processes involved and co-design activities with growers. This project is mainly a research project due to the exploratory deployment of innovative practices that need to be assessed. However, apple growers will be involved, as members of the partners' network (GRAB), by participating to co-design workshops or by testing innovative practices. The sustainability of the experimented orchards will be evaluated using the multicriteria assessment tool DEXiFruits (Alaphilippe et al 2015) to account for economic, environmental and social performances.

This project will provide i) basic knowledge on processes and within-time and –space interactions in complex agroecosystems such as orchards ii) methods and means of action to be applied by growers to (re)design their orchards for more resilience and iii) an opportunity to experience an original way to produce and disseminate knowledge. This will be realized by sharing knowledge, experiences and expertise among scientists engaged in IPM but coming from various disciplines, geographic contexts and working on different ecological processes. Moreover, sharing the approach with end-users will contribute to the dissemination of both innovative solutions and design methods towards more sustainable apple production.

The consortium was built to comprise a range of geographical and climatic situations from Northern to Mediterranean Europe, and a range of scientific skills including agronomy, entomology, ecology, chemical ecology and plant ecophysiology (Appendix 3). The coordinator is a specialist of multicriteria evaluation and sustainability assessment of apple cropping systems. Moreover, all teams are interested in a systemic approach of fruit production, i.e. in orchard design and management towards more sustainability through combinations of levers to control pests. Last, all partners can provide experimental and/or commercial organic or IPM orchards for experimental purpose and have established collaborations with growers' organisations.

To organize activities and team interactions, 4 transversal work packages (WP) involving all teams beside the general management (Fig 2) are proposed:

WP1. **Methodological and organizational aspects for knowledge sharing**, including shared framework, protocols and experiments;

WP2. **Design of systems with lever combinations and orchard co-design** adapted to local conditions and involving growers;

WP3. Knowledge enhancement through specific experiments when processes, lever implementations or interactions between levers are insufficiently understood;

WP4. Sustainability assessment using DEXiFruits to assess the experimented systems after adaptation of this tool to context conditions in Europe.

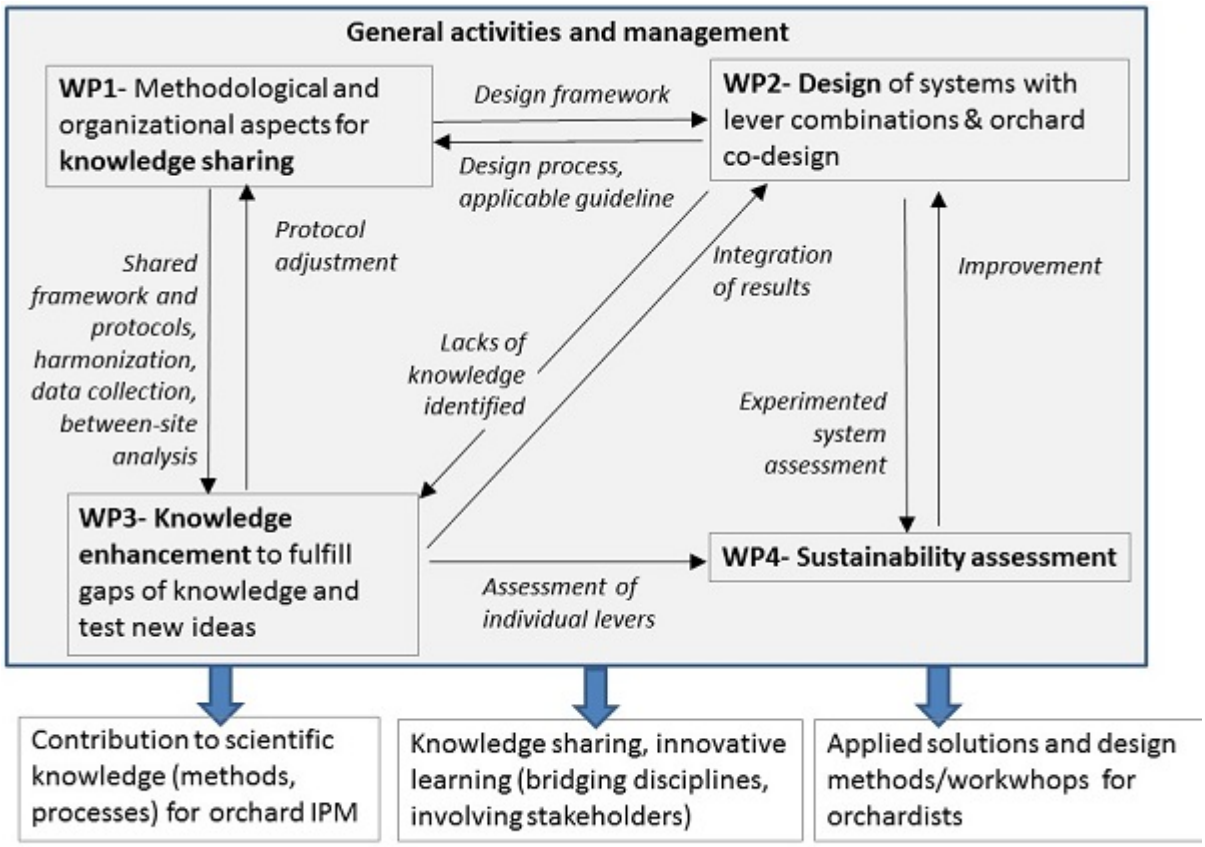


Figure 2. Project organization

Along the project, individual and/or combined levers will be tested on each site (WP2, WP3), and the overall performance of the corresponding orchards will be evaluated (WP4). An accurate description of sites, contexts, biotic and abiotic conditions and orchards will permit to identify suitable conditions for the use of those levers. A crossed analysis among countries will be carried out to improve the tested combinations through feedbacks and experience sharing (WP1).

The kick-off meeting will be a key step to share views and expertise and to propose a common framework (from Fig 1) as guideline for further work. The common models, study objects, methods and approaches between partners will be discussed to decide experimental within- and between-site activities to carry out in API-tree. Each annual meeting will permit to share advances, discuss results, issues and perspectives, and adapt protocols and the evaluation tool. For cost saving, those annual meetings will be backed to orchard field visits or workshops with end-users for exchanges on results and approaches, and/or to involve them in a co-design process (WP2). Another annual meeting through videoconference will permit to discuss on-going experiments. Videoconferences will also permit exchanges between two or more partners on common topics. A closing meeting (e.g. workshop) open to scientists and stakeholders will be held. Information sharing will be supported by computer applications (e.g. shared files), but also visits and co-supervision of trainees.

Deliverables, milestones and activities are presented in the Gantt chart (Fig 3) and Tab 1 (also available in Appendix 4). General activities and management represent a total of 10.6 person.months (pm) of which 5.1 pm for coordination (INRA) (Appendix 2).

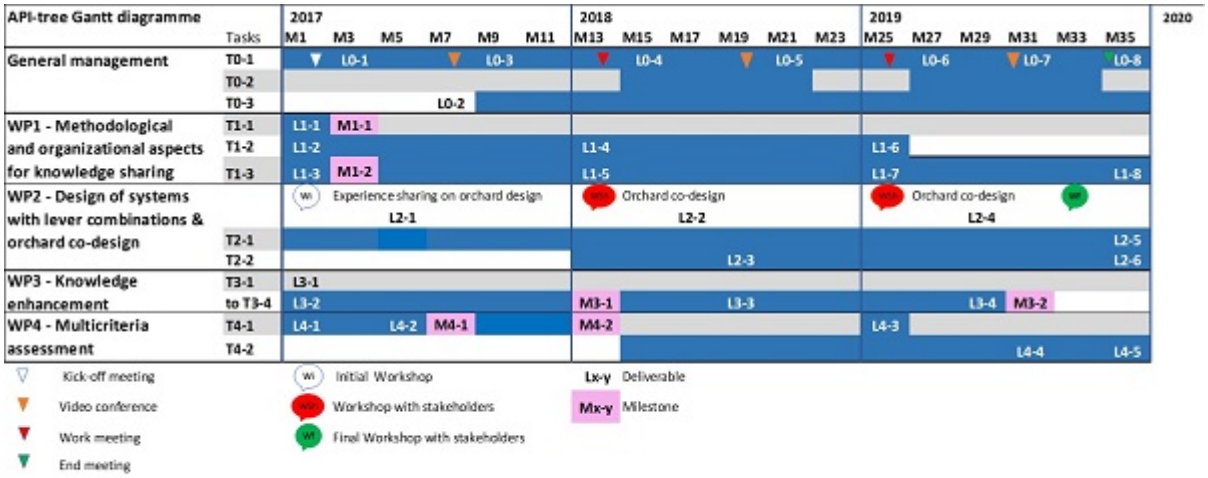


Figure 3. Gantt chart

Work packages	Tasks	Activities	Deliverables Lx-y / Milestones Mx-y
General management*	T0-1	Meetings, reporting	L0-1, L0-3, L0-4, L0-5, L0-6, L0-7 Meeting reports L0-8 Final report
	T0-2	Co-training	
	T0-3	Webpages	L0-2 Webpages available
WP1 - Methodological and organizational aspects for knowledge sharing	T1-1	Common framework	L1-1 Common framework finalized
			M1-1 Common framework available
	T1-2	Sharing specific protocols	L1-2 Grid to analyse specific protocols
			L1-4 Shared & harmonized specific protocols
			L1-6 Feedback on specific protocols
	T1-3	Common experiments	L1-3 Common experiments: protocols
			M1-2 Common protocols available
			L1-5, L1-7 Feedbacks on common experiments
			L1-8 Protocols available on-line (records)
WP2 - Design of systems with lever combinations & orchard co-design	T2-1, T2-2	Workshops	L2-1, L2-2, L2-4 Workshop reports
	T2-1	Orchard design	L2-5 Guideline for orchard design
	T2-2	Co-design	L2-3 Report on co-design process
			L2-6 Publication on orchard (co)design submitted
WP3 - Knowledge enchancement	T3-1 to T3-4	Specific experiments on studied levers & common experiments	L3-1 Detailed list of skills & experimental facilities of partners
			L3-2 Report on lacks of knowledge on studied processes
			M3-1, M3-2 (Parts of) studies on processes completed and feedbacks to WP2
			L3-3, L3-4 Publications or congress communications by partners on specific experiments
WP4 - Multicriteria assessment	T4-1	DEXiFruits adaptation to European contexts	L4-1 Demo on DEXiFruits tool (files)
			L4-2 Report on context specificities for tool adaptation
			M4-1 Context specificities identified
			M4-2 DEXiFruits adapted to each European context
			L4-3 Feedback on advantages/ limits of the tool
	T4-2	DEXiFruits use on experimented orchards	L4-4 Report on common results analysis
			L4-5 Final analysis & report

Table 1. Project deliverables and milestones

WP 1. Methodological and organizational aspects for knowledge sharing, M1-M36 (leader T. Hance, UCL, Belgium, 2 pm; INRA 4.4 pm & 1 pm trainee; UCPH 0.5 pm; GRAB 0.75 pm; SLU 1 pm; CRA-W 1.5 pm; IRTA 2 pm; SERIDA 1.5 pm)

T1-1. Common framework

A conceptual framework will be developed on the basis of the studied ecological processes (Fig 1) and related functional traits of plants, pests and NE, to provide a common frame for integrating results from WP3 and to discuss orchard redesign in WP2. Such methodological framework will document the approach but also increase the genericity of our results.

T1-2. Protocols sharing

To share protocols and formats of datasets for between-site analyses, important information to consider in a descriptive grid is related to site and context, studied pests and NE, studied processes and levers, sampling techniques, damage and predation/parasitism estimations, agronomic monitoring, data management and analysis, applications in orchards etc.

Following the kick-off meeting, protocols will be collected then analysed to be shared and/or harmonized along the first year of the project to analyse data from various sites on the same pests, NE and processes. Data management under the same format will permit crossed analyses. Experiments that will not take place in the first year will benefit from adjustments and formalization of previous experiments. Between-site analysis will take place at the end of each year, and a between-year analysis will also be carried out in each site and between sites.

T1-3. Common experiment

Since between-site analyses are constrained by context-dependent factors, a common experiment will be proposed on aphids which are studied in each country. Two common simplified protocols will be carried out on at least one site per country in years 1 and 2 in organic or untreated orchards:

(1) Visual observation of aphids and NE (presence/abundance) in aphid colonies in spring to document aphid infestation and the predatory complex in various European sites and provide context for other experiments;

(2) Measures of tree growth and rosy apple aphid infestation in the same trees in the next Spring (e.g. after bloom) to correlate tree vigour in Autumn (period of aphid return flight) and Spring tree infestation resulting from aphid return flight success before sexual reproduction.

WP 2. Design of systems with lever combinations and co-design, M1-36 (leader M. Tasin, SLU, Sweden 16 pm; INRA 7.1 pm & 5 pm trainees; UCPH 0.5 pm; GRAB 3.25 pm; UCL 1 pm; CRA-W 1.6 pm; IRTA 5.5 pm; SERIDA 1.5 pm)

The design of pest suppressive orchards will rely on knowledge sharing between partners, and between partners and growers. The designed systems will be based on combinations of levers adapted to local conditions and will be set in the field by adapting existing orchards. Lever combinations will be discussed among partners to benefit from expertise from other regions, on other pests or processes. Interactions to be managed are partly related to orchard design and attractiveness for naturally occurring or released NE: the dispersion of individuals out of the orchard following parasitoid mass release is difficult to avoid. Conversely, food resources can also act as a 'sink' for NE and divert them from prey in the apple tree (e.g. Marliac et al 2015). Finally, when insects are released, the presence of flower strips could help prevent this dispersion by providing parasitoid NE with nectar resources (UCL, CRA-W). Two entangled aspects will be developed:

T2-1. Design of sustainable orchards

Starting from the common framework (WP1), partners will share knowledge and experiences to combine levers and design pest suppressive orchard systems. Lacks of knowledge will also be identified at this step and handled through literature, other projects and/or WP3. Trade-off will be necessary to propose consistent systems and choices will of course be done differently according to each country. Those systems will be discussed and/or tested among partners but also through the network of each partner (e.g., GRAB will experiment lever combinations in commercial orchards) and in specific workshops (see below). Innovative orchards can also originate from existing orchards through step-by-step improvement. One important task will be to document steps in the design process, choices, expected interactions and results to propose a generic guideline for orchard design (e.g. describe context, set objectives in all orchard stages, spatial design and management across years, etc.) to be tested then proposed to growers and advisors at the end of the project.

T2-2. Co-design workshops

In Sweden (SLU) and France (GRAB, INRA), a workshop will be held to co-design orchards and/or lever combinations with stakeholders in 2 years of the project depending on local possibilities. The aim of such workshops is to bring together different competences, both practical and academic, to be integrated in co-design. The outcomes of the workshop will be new orchard systems. A partner of each country will attend at least one workshop, benefit from and contribute to it. Feedback on the action will be produced by all partners and stakeholders attending the workshops as reflexive analysis on the co-design process and opportunities it offers.

WP 3. Knowledge enhancement, M1-32 (leader L. Sigsgaard, UCPH, Denmark 17.5 pm; INRA 9.9 pm & 22 pm trainees; GRAB 3.5 pm & 6 pm trainees; UCL 7 pm; SLU 5 pm; CRA-W 6.9 pm; IRTA 12.25 pm; SERIDA 15 pm)

In close relationship with WP2 (Fig 2), the aim is to identify levers for which not enough knowledge is yet available for them to be used in combination within systems, or for which data are not available under a range of context conditions. This task may also consider interactions between levers. Some levers are not yet applicable in combinations within systems. This is true regarding lever 5 (ant diversion) and lever 6 (mass-release of predators and parasitoids in orchards). The use of plant diversity as a lever is developed in WP2, but detailed studies of novel diversity elements will also be included in WP3, such as the planting of aromatic plants in Northern Europe: exchanges with Southern partners are then highly relevant. Levers studied in WP3 will progressively be assessed during the course of the project, and most

promising methods/biocontrol agents will be integrated in orchards in year 3 or at least tested in field conditions. The following experiments on levers or processes of Fig 1 are proposed (Appendix 1):

T3-1. Experiments on levers 1 and 2

Planting susceptible cultivars as trap plants (CRA-W) and companion plants such as repellent aromatic plants (INRA) will be tested on the rosy apple aphid in Northern and Southern orchards. Spatial and temporal dynamic of plant volatile emission and effects on NE will be measured (INRA). The diffusion of selected essential oils in the orchard will be tested against sawfly (GRAB). Beside pest control, the aim of the experiment is to optimize the application of essential oils by using diffusers. All those levers will be assessed for their efficacy to act as push, pull or barrier, and on feasibility and costs (WP4).

T3-2. Experiments on lever 3

To optimize bottom up processes, several aspects will be considered:

-The effect of N tree nutrition on aphid infestation will be studied by comparing aphid infestation under different levels of N supply in an experimental orchard using a dynamic monitoring of N leaf content and aphid infestation (INRA);

-The effect of bud phenology on i) blossom weevil attack and ii) the parasitism rate affecting this pest will be assessed by comparing cultivars differing in their budburst period (SERIDA) expecting that a phenological mismatch between cultivars and blossom weevil phenology could affect pest damage;

-The effect of cropping system (rootstock, fertilization and weed management in the tree-row) on aphids will be assessed in an already established experimental orchard (SERIDA) using artificial infestation to avoid differences in the natural aphid infestation of trees.

T3-3. Experiments on lever 4

Top-down processes mediated by NE will be one of the core elements of this project, since all partners are experienced on these processes. Flower strips (CRA-W, UCPH, IRTA, INRA) and other cover crops (SERIDA, IRTA), as well as pesticide-free overwintering areas (SLU), will be tested using results obtained in related projects (EcoOrchard, Ecofruit):

-The effect of plant diversity, food resource or habitat management on the arthropod community (both pests and NE) and their dispersal from the agroecological infrastructures to the apple trees is considered by all above-listed teams;

-Pest suppression ecosystem service will be estimated by using sentinel preys (UCPH, INRA, IRTA) and molecular gut content analysis of field-sampled aphid predators in a shared experience (UCPH, INRA)to identify predatory species contributing to pest control in Northern and Southern orchards. A selection of predatory arthropods will be sampled in organic apple orchards in Spring and Summer as a function of distance to flower strips and other agroecological infrastructure. In addition, aphid infestation levels in the orchards and predator feeding trials in the laboratory will permit to assess overall predator contribution to control the rosy apple aphid in orchards;

-The effect of groundcover management in the alleys, e.g. through alternate shredding on half alley, will be evaluated for the provision of spontaneous flowers and the presence of aphid predators such as hoverflies (SERIDA).

Finally, promoting insectivorous birds will be made by providing artificial nests (e.g. Mols & Visser 2002) in 10 commercial orchards. Nesting will be monitored and avian predation will be estimated through feeding attempts on plasticine models mimicking caterpillars (Barbaro et al 2014) and by comparing aphid density in artificially infested branches with and without bird exclusion mesh (SERIDA).

T3-4. Experiments on levers 5 & 6 (direct methods)

The diversion of ants with alternative prey or sugar baits will be considered (INRA, IRTA) as well as the development of ant disruptive formulations (SLU). The expected result is that ants will neither attend aphid colonies in the tree nor ‘transplant’ aphids on non-infested shoots because of diversion; aphids will therefore be more exposed to diseases and NE and spread more slowly in the tree.

Augmentative releases of predatory arthropodscan supplement the naturally occurring complex to increase biocontrol. Early releases of predatory insects such as earwigs will be tested (INRA, IRTA), as well as *A. bipunctata* and anthocorids (UCPH), and will benefit from activities of ongoing projects (EcoOrchard, PROTECFRUIT). Interactions of the selected predators with other organisms of the apple orchard will be studied at the laboratory to predict the efficacy of the release (UCPH).

Parasitoid populations and their effectiveness to control aphids will be evaluated in relation with the precocity of the mass release to control *D. plantaginea* development (UCL, Belgium). Inoculative release of *M. ridens* parasitoid (authorization under consideration at the French

ANSES agency) in 5 commercial organic orchards (Sebiopag facility) will be the first experimental introduction in Europe of an exotic NE to control codling moth. The monitoring of *M. ridens* establishment and its expected expansion will address population dynamics, efficiency and impact on the native parasitoid community. This will contribute to understand how landscape features affect *M. ridens* population growth and dispersal and may favour or impair biocontrol efficiency.

WP 4. Sustainability assessment, M1-36 (leader A. Alaphilippe, INRA, France 9.1 pm & 2 pm trainees; UCPH 0.25 pm; GRAB 0.75 pm; UCL 0.2 pm; SLU 1 pm; CRA-W 0.2 pm; IRTA 2 pm; SERIDA 0.2 pm)

Specific attention will be paid to the agronomic performances, the feasibility and the costs of the proposed combinations of levers. Such ex-post evaluation will be carried out using DEXiFruits tool on the systems experimented during the project but also possibly on systems designed in former or on-going projects for comparison purposes. DEXiFruits will be adapted to European context conditions if necessary. Main steps are:

T4-1. DEXiFruits adaptation to European contexts

This includes i) the survey of existing innovative orchard systems among partners through data monitoring; ii) the use of the tool on datasets provided by partners; iii) feedbacks on the outputs to identify country specificities and to format the evaluation tool to each European context. This will also permit to identify the limits and the perimeter of use of DEXiFruits.

T4-2. Evaluation of experimented orchards

The evaluation of experimented orchard systems of partners or of single levers will focus on feasibility, constraints and costs to provide growers with an overall evaluation of the proposed solutions. Dashboards or radar diagrams will be produced to help identify advantages and limits of the evaluated systems. Discussions about the performances and limits of the designed orchards will open possibilities for improvement through the integration of other levers or the optimization of the selected ones.

Finally, expected results are:

-Knowledge on ecological processes in orchards;

-Identification of combinations of levers which can be implemented in different contexts, with information on their efficacy, mode of action, feasibility and costs, and possible unexpected interactions;

-Design of orchard systems allowing for the natural control of the main insect pests in a range of contexts;

-Extended application of DEXiFruits tool to assess apple cropping systems;

-Knowledge sharing and interactions among scientists from various disciplines and stakeholders;

-Sustainability assessment of orchards providing information to discuss implementation possibilities with advisors and growers;

-Innovative networking for methods, experiments, training and implementation of collective intelligence to develop an integrated agroecosystem approach for apple pest control.

RELATED PROJECTS

The projects related to API-tree are:

RegPuc (2016-2018): Onema Ecophyto 2018 program, 45 k€; Partner INRA PSH.

It aims to assess the consequences of a moderate reduction (by 20%) of nitrogen and water inputs on (i) fruit yield and quality, (ii) tree resistance to aphids and (iii) preservation of wood quality (flowering ability) in a commercial peach orchard along 3 years.

Peerless (2013-2017): French ANR program Agrobiosphere, 800 k€; Partner INRA. Predictive Ecological Engineering for Landscape Ecosystem Services and Sustainability.

Objectives are potentially linked to the API-Tree project through: (1) the identification of cropping systems and landscape characteristics for which the biodiversity functionally enhances crop production; (2) the design of viable deployments of alternative crop systems and semi-natural habitats in spatially explicit landscapes. One of the studied crop is apple orchard. The project includes knowledge enhancement on the ecological processes of pest-NE interactions but the optimisation of alternative cropping systems is mainly based on simulation models at larger spatial scales than in the API-Tree project.

Sebiopag (2014-2017): ECOPHYTO FRB program; Partner INRA.

Long term survey of the biodiversity in the agricultural landscape, including a network of commercial apple orchards in the Basse-Durance Valley, South-Eastern France (http://sebiopag.inra.fr/)

BIOCCYD (2015-2017): Ecophyto PSPE2, coord. N. Ris, INRA ISA-RDLB, 300 k€.

BIOMODICS (2013-2017): FP7 – Marie-Curie – IRSES, coord. T. Malausa, INRA ISA-BPI, 180 k€.

Both projects are focused on research and development in classical biological control with the experimental program for the introduction of *M. ridens* against codling moth in France. Those projects allowed us to import populations of *M. ridens*, improve rearing technology for *M. ridens* and its host, develop the microsatellite markers, and carry on all the laboratory tests necessary to obtain the authorization to release this biological control agent in the field. However, the timelines for these projects won't cover the field campaigns for introduction and extensive monitoring.

Protecfruit (2014-2017): GUDP/DAFA, 426 k€; PartnerUCPH. Protected production of organic apple and pear.

EcoOrchard (2015-2018): EU Core-organic plus/DAPA, coord. L. Sigsgaard, UCPH, 166 k€. Innovative design and management to boost functional biodiversity of organic orchards

In DK, ongoing experiments are conducted in five organic apple orchards with already established wild flower strips substituting a row of apple trees (Protecfruit) and in one organic apple orchard with wild flower mixtures in the orchard alleys (EcoOrchard). The effect of flower strips on aphid density will be established in these two systems. The predation level (sentinel prey) and the predator complex (beating samples) will also be determined. The outcome of such extensive field studies allows for a continuation of more detailed studies of predator-prey interactions. Such studies are of great value to understand the mechanisms in the above-ground environment of organisms as well as creating a good basis for developing biological control strategies.

INIA (2014-2017): Spanish government, 154 k€; Partners SERIDA, IRTA.

Ecosystem services to promote pollination and pest control of woody crops: effects of landscape and management.

Objectives potentially linked to the API-Tree project are the implementation of ecological infrastructures and management strategies that promote natural biological pest control. Specifically, the activity presently proposed by SERIDA of studying the effect of alternative groundcover management on provision of flowers and natural enemies will continue the experiment settled in this Spanish project.

EcoFruit (2015-2017): ERA-NET BiodivERsA, 745 k€; Partner SERIDA.

The role of birds on the control of apple pests is studied in Spain.

DISSEMINATION

A consortium agreement for intellectual property will be established between partners if the project is supported. The idea is that research work specifically carried out by a partner or some partners will belong to those partners, and collective work will be published collectively and could not be used by a sole partner unless approval of all other partners.

The dissemination of the research will target two publics i) the scientific community and ii) end-users, including growers and advisors, and possible other stakeholders.

Each partner will communicate on his/her results and collective results using the resources of his/her institute, his/her network, usual channels and support offered by other projects (e.g., EBIO-network athttp://ebionetwork.jki.bund.de/). This will ensure that some of the results will be available in the country native language, especially for end-users. Beside, a dissemination plan will be established to communicate on the approach and the collective results. This includes: a talk or a poster in a congress on cropping system design, the organization of field-days, the organization of workshops gathering scientists and stakeholders, on-line records hosted by already existing websites related to IPM (e.g., http://www6.inra.fr/quantipest). Webpages on the project will be created and hosted by institutional website (coordinator).

Scientific articles, congress talks and shared protocols (on-line records) will mainly target the scientific public. At least one scientific article or congress talk on the overall approach, and one scientific article or congress talk on each specific studied process will be produced.

Dissemination towards end-users will include: reports and technical articles in each country, leaflets or on-line records on specific methods to control pest, guidelines to (re)design orchards, technical workshops and field day demonstrating (e.g., flower strip management and push-pull experiment).

SOCIETAL AND ETHICAL ASPECTS

Apple tree (*Malus* × *domestica* Borkh.) is the most common fruit tree that represents 450,000 ha in Europe and 35% of the total orchard surface area (Eurostat, 2014). Around 14 million tons of apple are produced per year in the EU. Fruits are considered to be healthy products, but the heavy reliance on pesticides of apple production questions this assertion.

Such reliance can be explained by a long growing season (up to 8 months), a perennial cropping system where many pests can develop and build up large populations across years, the use of susceptible cultivars and market standards requiring fruit with no visual default. There is an increasing concern among citizens and consumers about the attested presence of pesticide residues in the environment and food. In response to the societal demand for more sustainable practices in agriculture, policy measures to decrease the reliance on pesticides (e.g., European directive n° 2009/128/CE) have been implemented and the most health-concerning pesticides were withdrawn in the EU in the last decade. However, this also reduced the number of compounds available for pest control, thus increasing the risk of pesticide resistance in pest populations and therefore the failure of chemical control. Last, the usual control of apple aphids relies on neonicotinoid compounds which are under scrutiny because of side-effects on bees.

Apple production thus faces bottlenecks. The design of IPM innovative fruit production systems is a key point to maintain a sustainable apple production in Europe, and to avoid environmental and food contamination as well as health problems due to the exposure of workers to pesticides. The present project will contribute to such design, and will pay attention to the way innovative orchards can be (re)designed and implemented by the growers who will be involved in the design process.

Another key-point of the project will also rely on the approach. To tackle complex issue such as pesticide use reduction, analytical approaches that simplify a given system into smaller parts and single processes before study are not efficient. The whole system and its interactions (i.e. the orchard) are to be considered as a framework to develop research. Moreover, the design of agroecological systems will require sharing knowledge from various sources to consider the agroecosystem complexity and farm organizational constraints. In our project, knowledge sharing through meetings, visits, workshops, co-training of students, common experiments... will be a first step that permits to consider a generic common framework to merge scientific knowledge from various disciplines, technical knowledge and know-how. Such global perspective along with the involvement of growers in the design process is important for further adoption of the (re)designed systems, and also to benefit from experienced stakeholders. Our project therefore offers an opportunity to experience an original way to produce and disseminate knowledge towards sustainability.

FINANCES

Requested funding

Organisation name	Funding agency	Personnel	Travel	Consumables / Equipment	Subcontracts	Requested Funding	Total Own Contribution	Total Costs
Institut national de la recherche agronomique	MAAF	81000	24000	37000	4000	151840	69000	220840
Overhead		3240	960	1480	160			
University of Copenhagen	DAFA	101119	4027	18792		178472	23356	201828
Overhead		44494	1772	8268				
GRAB Research Group for Organic Farming	MAAF	35392	4000	4000	2000	47128	15728	62856
Overhead		1416	160	160				
Université catholique de Louvain	SPW-DGO3	41100	3000	3500		49980	5500	55480
Overhead		2055	150	175				
Swedish University of Agricultural Science	FORMAS	117511	6000	19854		215061	0	215061
Overhead		71696						
CENTRE WALLON de RECHERCHES AGRONOMIQUES	SPW-DGO3	41100	4000	2500		49980	5500	55480
Overhead		2055	200	125				
Institut de Recerca i Tecnologia Agroalimentaries	INIA	39000	5038	6100		60166	23268	83434
Overhead		7800	1008	1220				
Servicio Regional de Investigación y Desarrollo Agroalimentario	INIA	23000	7000	4000	16000	60000	24000	84000
Overhead		4600	1400	800	3200			
TOTAL		616578	62715	107974	25360	812627	166352	978979

Own contribution

Organisation name	Personnel	Travel	Consumables / Equipment	Subcontracts	Other	Total Own Contribution
Institut national de la recherche agronomique	69000					69000
University of Copenhagen	23356					23356
GRAB Research Group for Organic Farming	15728					15728
Université catholique de Louvain	5500					5500
Swedish University of Agricultural Science						0
CENTRE WALLON de RECHERCHES AGRONOMIQUES	5500					5500
Institut de Recerca i Tecnologia Agroalimentaries	23268					23268
Servicio Regional de Investigación y Desarrollo Agroalimentario	24000					24000
TOTAL	166352	0	0	0	0	166352

Aude Alaphilippe
savage@paca.inra.fr

Prof. : 460, Domaine de Gotheron
26320 SAINT MARCEL LES VALENCE
0033 + (0)4 75 59 92 00

Nationality	French
Date of birth	20/08/1980
Place of birth	REIMS (FRANCE)

RESEARCH PROJECT: it is focused on the design and multi-criteria assessment of innovative orchard systems in order to improve their performances and sustainability.

SKILLS:

Agronomy	Fruit production system, Integrated and organic production
Multicriteria assessment	Life cycle analysis, Synops, tool development for sustainability assessment

WORK EXPERIENCE

• Date (da – a)	From 01/11/2008
• Name of employer	INRA institut national de recherche agronomique, FRANCE
• Description	Researcher (IR) multicriteria assessment of tree protection strategies
• Date (da – a)	From 2014
• Name of organisation	IOBC
• Description	Member of the IOBC IP commission guidelines
• Date (da – a)	From 01/04/2008 to 31/10/2008
• Name of employer	ARMEL, Technical center FRANCE
• Description	To test new production methods with farmers
• Date (da – a)	From 01/04/2004 to 31/12/2007
• Name of employer	SafeCrop / Istituto Agrario di San Michele All'Adige
• Description	Project collaborator: non target effects of a biocontrol agent/ mechanism study
Diplome	PhD Student (final PhD exam June 2008)

STUDIES

• Dates	September 2002 to nov. 2003
• Name and type of organisation providing education and training	ENSAR (Ecole Nationale Supérieure d'Agronomie Rennes) Associated with INA Paris-Grignon, ENSA Montpellier
• Title of qualification awarded	Specialization in Plant Protection (Ingénieur Agronome)
• Dates	September 2000 to nov. 2003
• Name and type of organisation providing education and training	Ecole Nationale Supérieure d'Horticulture et d'Aménagement du Paysage ENSHAP, INH (Angers, France)
Principal subjects/occupational skills	Horticulture sciences and Project Managment
• Title of qualification awarded	Master degree in Horticulture sciences

MOTHER TONGUE	FRENCH
OTHER LANGUAGES	ENGLISH, ITALIEN, GERMAN

PUBLICATIONS

PEER REVIEWED PUBLICATIONS

Alaphilippe, A.; Boissy, J.; Simon, S.; Godard, C. 2016. Environmental impact of intensive versus semi-extensive apple orchards: use of a specific methodological framework for Life Cycle Assessments (LCA) in perennial crops. Journal of Cleaner Production 127, 555-561. Doi:10.1016/j.jclepro.2016.04.031

Hennen W. and Alaphilippe A. 2015 PREMISE Insect Model: Integrated Population Dynamics Model for the Ex-ante Evaluation of IPM against Insect Pest. Journal of Agricultural Sicience and Technology B 5; 231-240. Doi: 10.17265/2161-6264/2015.04.001

Alaphilippe A., Simon S., Hayer F. 2014. Using Life Cycle Analysis to analyse the environmental performances of Organic and Non-organic apple orchards. Chapter 12: 231-238. In: Organic Farming, Prototype for sustainable agricultures. Eds. Bellon S. and Penvern S. Springer. Pp489. Doi: 10.1007/978-94-007-7927-3.

Alaphilippe A., Simon S., Brun L., Hayer F., Gaillard G. 2013. Life cycle analysis reveals higher agroecological benefits of organic and low-input apple production. Agronomy for Sustainable Development 33(3): 581-592. Doi: 10.1007/s13593-012-0124-7

Pauget B., Gimbert F. Coeurdassier M., Crini N., Peres G., Faure O., Douay F., Hitmi A., Beguiristain T., Alaphilippe A., Guernion M., Houot S., Legras M., Vian JF., Hedde M., Bispo A., Grand C., de Vaufleury A. 2013. Ranking field site management priorities according to their metal transfer to snails. Ecological Indicators 29: 445-454.

Mouron P., Heijne B., Naef A., Strassemeyer J., Hayer F., Avilla J., Alaphilippe A., Höhn H., Hernandez J., Gaillard G., Mack G., Solé J., Sauphanor B., Samietz J., Patocchi A., Bravin E., Lavigne C. Bohanec M., Ursula Aubert U., Bigler F. 2012. Sustainability assessment of crop protection systems: SustainOS methodology and its application for apple orchards. Agricultural Systems 113 1–15. Doi:10.1016/j.agsy.2012.07.004

Alaphilippe A., Elad Y., Rav david D., Derridj S., Gessler C. 2008. Effects of a biocontrol agent of apple powdery mildew (*Podosphaera leucotricha*) on the host plant and on non-target organisms: an insect pest (*Cydia pomonella*) and a pathogen (*Venturia inaequalis*). Biocontrol Science and Technology: 18(1-2):121-138. Doi: 10.1080/09583150701818964

OTHER RELEVANT CONTRIBUTIONS & PROJECTS

Registration of two tools dedicated to the sustaibility assessment of orchard production system: DEXiFruits® and DEXiPM-pomefruit® http://wiki.inra.fr/wiki/deximasc/DEXiFruits/1-+Accueil

Coordinator of a National project: DEXiFruits dedicated to the development of an easy-to-use tool dedicated to the ex-post assessment of the sustainability of fruit production systems.

The PURE European project (FP7): Task leader/ multicriteria assessment of IPM control methods and apple production systems.

Co-coordinator of a National project: Alt'Carpo dedicated to the study of mode of action, efficacy and sustainability of exclosure netting against the codling moth on apple tree.

University of Copenhagen (UCPH), Faculty of Science, Depart. of Plant and Environmental Sciences
UCPH is the largest university in Denmark covering natural resources and life sciences. It has numerous co-operative projects with national and international partners and professional experience in EU projects and other major international grants. The university is among the EURO League of Life Science universities. The Department has modern, well-equipped laboratories for work on biological control agents and a well-established network with IPM and organic apple growers. Team leader is assoc. professor Lene Sigsgaard, team members postdoc Stine Kramer Jacobsen and lab technician Kristian Hansen. The project will have synergies with the DAPA supported projects CORE Organic + EcoOrchard and PROTECFRUIT, aiming at designing apple IPM systems

Curriculum vitae –Lene Sigsgaard

PERSONAL DATA

University of Copenhagen, Faculty of Life Sciences, Dept. of Plant and Environmental Sciences,
Thorvaldsensvej 40, DK-1871 Frederiksberg C Denmark, Ph. +45 35332674/ +45 21151827
Year of birth: 1961, Nationality: Danish, Marital status: Married, 2 children

Research group: http://plen.ku.dk/english/research/organismal_biology/applied_entomology/

ACADEMIC DEGREES

1992 - 1996: Royal Veterinary and Agric. University (KVL), PhD in agricultural entomology.
1982 - 1989: KVL. MSc. in Agricultural Sciences, main subjects in insect-plant interactions.

EARLIER POSITIONS (TITLE EMPLOYER, YEAR)

Assoc. Professor	Univ. Copenhagen, Faculty of Science	Denmark	2006-
Assoc. Professor R&D	KVL, Dept. Ecology (1/2 -02- 15/9-05)	Denmark	2002-2005
Assistant Professor	KVL, Dept. of Ecology	Denmark	2001-2002
Coll. Research Scientist	International Rice Research Institute	Philippines	1998-2001
Researcher	Danish Agricultural Research Institute	Denmark	1996-1998
Assistant Scientist	KVL (at ICRISAT 1992, 1993)	Denmark	1992-1995
Assistant Scientist	KVL, Dept. of Agricultural Sciences.	Denmark	1989-1992
Consultant	IMP, (Biological control) (3 mo/year 07-11)	Kenya	2007-2011

Maternity leave 1991-92, 6 months, 1994-95, 6 months

EXPERIENCE OF LEADERSHIP AND PROJECT MANAGEMENT

(details 2010-) Headed 18 research projects, participated in several others. *Headed by LS:* EU CORE Organic/GUDP ECOORCHARD 2015-17, Danish EPA 09-11: 'Biological Control of tortricids and aphids in strawberry'; Danish lead in EU CORE organic Softpest Multitrap 2012-14
LS participant:The Danish Council for Independent Research, Technology and Production Sciences, Optimizing performance of biological control agents used in Integrated Pest Management 2015-2018, GUDP Protecfruit 2013-2017, Strategic Res. Council 2012-2015: Imbicont -Improved biological control for IPM in fruits and berries (UCPH in collab. Univ Sao Paulo, Br), EU FP7 2012-2015 Inbiosoil - Innovative biological products for soil pest control, The Danish AgriFish Agency, Organic RDD 2011-14 Fruitgrowth. Danish fruit and berries: Novel organic solutions securing future growth w Aarhus Univ, growers, industry and advisory services ; FFU: 2011-16: Productivity and growth in organic value chains ProGrOV(10 mill DKR, ca 0.8 mill UCPH)

RESEARCH PROFILE

Ecological studies of insect-plant and predator-prey interactions and biodiversity in scales from individual to community aiming at developing sustainable production systems to promote natural regulation of insect pests, wild bees for pollination, and apply use of biological control.

SUPERVISION AND TEACHING

Guidance at BSc (6), MSc (15) and PhD (10) level. Presently main superviser of 3 PhD students and co-supervisor of 3 PhD students. Teaching courses in biological control, agricultural and horticultural entomology, plant protection and ecology. MSc courses in Insects in agriculture and Horticulture, Innovation inspired by nature and BSc course 'Faunaens vilkår i kulturlandskabet'

SELECTED PROFESSIONAL SERVICES

2013 **Scientific committee member** Associate professor in Agricultural Entomology, UMB, Norway
2012 **Panel Member** Agric. and Forestry Sciences, FCT, Lisboa, Portugal
2010 **expert**, EU monitoring review of CGIAR 2010 review of project application (Systerra) INRA
2009- **vice-president** IOBC-WPRS (Int. Org. for Biological Control, West Palearctic Reg. Sect)
2011, 2007 & 2003: Member of **scientific committee** assessing PhD theses at SLU
2006-11: Member of the **Pesticide Advisory Council** of the Danish EPA
2003-06 Member, **Int. Adv. Board** for Res. Excel. in Sustainable Pomology, (EU-FP5)
2003-10 **Board** Member. The Danish Society of Plant Diseases and Pests
Peer reviewed 52 papers for 18 ref. journals. Subj. ed. Encycl of the Earth 2008-11. Ed. board Frustula Entomologica (Italy) (2011-)

PUBLICATIONS

31 Peer-reviewed original articles. 28 proceedings, 2 book chapters, 4 research papers, 19 conference abstracts, 2 consultancy studies, 34 popular/technical papers, 4 bibliographies, 17 research reports, 50 conference abstracts

Research profile - Stine Kramer Jacobsen

The research of Stine Kramer Jaconsen (SKJ) is focused within studies of ecological dynamics between pests and their natural enemies, primarily arthropod predators, and biological control strategies. She has experience with biodiversity studies of plants and insects within cropping systems of strawberry and apple, its impact on pest and predator occurrence and is also investigating predator-prey dynamics by molecular methods (PCR). During her PhD she was a part of the international research project IMBICONT (Improved biological control for IPM in fruits and berries), and is currently working as a post doc in the projects EcoOrchard and PROTECFRUIT, investigating the impact of two types of wild flower strips on predator-prey dynamics in apple orchards. Publications include a peer reviewed article: Jacobsen, S.K., Alexakis, I., Sigsgaard, L. (2015) Antipredator responses in *Tetranychus urticae* differ with predator specialization. Journal of Applied Entomology. And an IOBC proceeding: Jacobsen, S.K., Eilenberg, J., Kingen, I., Sigsgaard, L. (2014) Different behavioral responses in specialist and generalist natural enemy interactions (predators and fungi) in a strawberry-mite pest system. From the IOBC VIII Workshop on Integrated Soft Fruit Production, Pergine Valsugana, Italy, May 2014.

Claude-Eric Parveaud
GRAB - Research Group
for Organic Farming
claudeeric.parveaud@grab.fr

460, Domaine de Gotheron
26320 SAINT MARCEL LES VALENCE
0033 + (0)4 75 59 92 08
0033 + (0)6 81 37 45 82

Nationality	French
Date of birth	22/06/1977

RESEARCH PROJECT: Improvement of the efficiency and resilience of organic fruit systems, focusing on pests and diseases control.

SKILLS:

Agronomy	Organic cropping systems Pests and diseases control Experience in setting-up on-station and on-farm experimental studies
Network & dissemination	Knowledge of the stakeholders in organic fruit production Multi-stakeholders dissemination

WORK EXPERIENCE

• Date	Since 2012
• Name of employer	ITAB Technical Institute for Organic Farming, FRANCE
• Description	Management of the organic fruit commission
• Date	Since 2009
• Name of organisation	GRAB Research Group for Organic Farming
• Description	Pests and diseases control in organic fruit systems, research in copper alternatives, assessment of cropping practices impacts, on-farm networking.
• Date	2006-2008
• Name of employer	SENuRA, experimental station FRANCE
• Description	Assessment of cropping practices to control Walnut blight
• Date	2002-2006
• Name of employer	INRA
• Description	Modelling of walnut tree growth and light interception using 3D virtual plants
Diplom	PhD Student
• Date	2001
• Name of employer	INRA
• Description	Agronomic assessment of new training systems for apple orchards through a on-farm plot network
Diplom	Engineer diploma

STUDIES

• Dates	2001-2002
• Name	Postgraduate diploma in Ecology, University Paris 6, INA Paris-Grignon, ENS
• Title of qualification	Postgraduate diploma in Ecology, specialization in functionnal ecology
• Dates	1999-2001
• Name	Agro-Montpellier School, Advanced Institute of Agricultural Science and Natural Resource Studies

• Title of qualification awarded	Agricultural engineer, specialization in Plant Production and Resource Protection
MOTHER TONGUE	FRENCH
OTHER LANGUAGE	ENGLISH, SPANISH

PUBLICATIONS

Parveaud C.E, Brenner J., Ondet S.J., Gomez C., Libourel, Warlop, Brun L., Mercier V., Clauzel G., Audergon J.M. 2015. Assessment of diseases susceptibility of peach cultivars in experimental plots and on-farm for organic and low-input systems. Baseline of French case studies. Symposium INNOHORT, ISHS, Avignon 8-12 June 2015.

Parveaud C.E., Brenner, J, Libourel G., Albert L., Guérin A., C., Mercier V. 2014. Verger Bas Intrants : La biodiversité fonctionnelle pour réduire les intrants phytosanitaires. Réussir Fruits & Légumes supplément n°342, September 2014, p.12.

Brun L., Lemarquand A., Orain G., Gros C., Combe F., Didelot F., Parveaud C.E., Gomez C., Parisi L. Effects of a cultivar mixture on scab control in apple orchards. ECOFRUIT, 16th International Conference on Organic Fruit Growing, University of Hohenheim, Germany, February 17 to 19, 2014

Parisi L., Gros C., Combe F., Parveaud C.E., Gomez C., Brun L. 2013. Impact of a cultivar mixture on scab, powdery mildew and rosy aphid in an organic apple orchard. *Crop Protection* 43, 207-212.

Gomez C., Parveaud CE., Libourel G., Romet L., Warlop F., Brun L., Simon S., Pouzoulet D., Delebecq A., Laurens F., Oste S., Tournant L. Sensibilité variétale aux maladies et ravageurs. Anciennes et nouvelles variétés en AB : Puceron cendré du pommier. Fiche n°7. Arboriculture Fruitière, March 2012.

CURRICULUM VITAE

Thierry Hance, Pr.
Head of the Biodiversity section
Earth and Life Institute (ELI)
Université catholique de Louvain (UCL)
Belgium

Professional Address

Earth and Life Institute, Biodiversity Research Center
Université Catholique de Louvain (UCL),
Place Croix du Sud, 5
1348, Louvain-la-Neuve
Tél. 010/47.34.93, Fax 010/47 34 90
E-Mail: Thierry.hance@uclouvain.be
http://www.uclouvain.be/239886.html

1. Education

- October 1989 - July 1990, post- doctoral fellowship, Eco-physiology of cold resistance in insect parasitoids, Agriculture Canada Research Station, St-Jean-sur-Richelieu, Québec
- 1988 PhD thesis in Ecology, population Biology, Université catholique de Louvain (UCL), Faculty of Sciences, Department of Biology.
- 1982, Msc in Zoology, Université catholique de Louvain (UCL), (UCL), Faculty of Sciences, Louvain-La-neuve
- 1980, Bachelor in Biology, University of Namur (UN), Belgium

2. Scientific Career

- 1982 - 1985 graduate fellowship from IRSIA, Belgium
- 1985 - 1988 research assistant, IRSIA, Ecology and Biogeography Research Unit, UCL
- 1989-1991 Senior Research assistant FNRS, Ecology and Biogeography Research Unit, UCL & Post Doc Agriculture Canada Research Station, St-Jean-sur-Richelieu, Québec
- 1991- 1998 Research associate FNRS, Ecology and Biogeography Research Unit, UCL
- 1996, Lecturer part time, UCL.
- 1998, Lecturer full time
- 2000, Professor, UCL
- 1996 to 2005, Head of the Ecology and biogeography research unit, UCL
- Founder and past president of the Biodiversity research centre (BDIV), UCL
- Founder and past director of the Doctoral school on Biodiversity (EDIV), UCL
- Co-founder (2004) of VIRIDAXIS, SA, Spin off of UCL and member of the advisory board
- September 2005 to August 2009, President of the Biology Department, UCL
- Octobre 2006, Senior Professor, UCL
- 2006-2009: Invited professor to the "Institut national d'agriculture, Tunis, INAT".
- 2012, Head of the biodiversity section of the Earth and Life Institut
- 2012, Vice-president of the Earth and Life Insitute

3. Prizes and honors

1) Travel fellowship, Ministère de la Communauté Française (1988), 92/100
2) Nato fellowship, 1989-1990, 10 months of postdoctoral stay in Canada
3) OCDE fellowship October 1994, 3 weeks stay in a research station of the Japan Ministry of Agriculture, , NIVOT, Kanaya, Dr. Yamaguchi.
4) Price Adolphe Wetrens 2001, Académie Royale des Sciences, des Lettres et des Beaux-Art, Belgium.
5) 2001, Invited professor FNDP, Namur, Ecoethology, 15h
6) May 2002, Invited professor, University of Rennes1, France.
7) Octobre 2003 : Honorary award for an outstanding contribution to forestry research in Romania, Ministry of Forest, Water and Environment, Romania

4. Publications

- 132 publications in international journals
- One patent
- 9 book chapters
- 28 publications in proceedings or national journal
- Cited 2805 times, H factor = 30 according to Google Scholar, 1507 citation and 21 factor H according to Scopus

5. Member of Jurys and selection or advisory boards

- Past Member of the Research Council of the Catholic University of Louvain
- Past Member of the research commission of the department of Biology (UCL)
- Member of the "Communauté Française de Belgique" jury for doctoral fellowship attribution (FRIA), since 1992
- Past Member of the advisory board of the Belgian Zoological Society
- Past Member of the Animal Biology commission, FNRS, Belgium (1998-2008)
- Project ranking in 1999 for the German Biodiversity Program
- Past Member of the Biosafty advisory council of the Belgian Government (1998-2010)
- Reviewer for several scientific journals : Biocontrol, Agriculture, Ecosystems and Environment, Journal of Economic Entomology, Journal of Environmental Entomology, Journal of Insect Physiology, PlosOne, European Journal of Entomology, Oikos, Journal of European entomology…
- President of all PhD Juries of the Biology department (UCL), 2005-2009.
- **Since 1995, PhD Jury member** of at least 3 PhDs per year for Biologist or bioengineer students at the UCL, Belgium. In other Belgian University, jury member of 4 PhD thesis, Université Libre de Bruxelles (2001 et 2003, 2011) and 3 for Agrobiotech (2011 Gembloux (2003). In France, jury member of 4 PhD thesis at University of Rennes1 in 1999, 2002 and 2003, 2011, one in Universtity St Denis, La Réunion (2009), one in Montpellier SupAgro (2010), and one in Lyon, Claude Bernard University (2011). In Tunisia, member of the jury of two thesis, INAT Tunis (2006 and 2015). In Holland, jury Member of 1 thesis, University of Amsterdam (2012) and in Sweden, jury member of 1 Thesis, University of Oslo, 2014, 2015 Jury member of 1 thesis Un iversity of Lile (France) and 1 thesis University of Auckland, New Zeeland.

6. Participation to international congress and meetings

- Participation to more than 51 international meetings or congress. Chairman and/or keynote speaker of several sessions. Abstract list available on request
- Organisation of « Biodiversity, from genes to landscape » UCL, 13-15 December2000, à Louvain-la-Neuve and The international biodiversity congress, April 2004, Louvain-la-Neuve
- Co-organiser of the Benelux Congress of Zoology, November 2004, Louvain-La-Neuve, Belgium
- Organizer of the 2010 "Conférence International francophone d'entomologie", 5 - 10 July 2010, Louvain-la-Neuve, 220 attendents
- Organiser of the " Réunion des Entomophagistes" 2-6 April 2014, Louvain-la-Neuve
- Member of the International Organizing Committee of the 2nd Global Entomology Conference, Kuching, Malaysia, 8- 12 November
- Keynote speaker of the 2nd Global Entomology Conference, Kuching, Malaysia, 8- 12 November

7. Thesis and post-doc

- Supervisor of 21 PhD thesis since 1997.
- Present supervisor of 8 PhD thesis
- Supervision of 14 Post-docs since 1997

8. Recent research projects and Financial supports;

- FRFC, 2012-2016. 12.500 €/year + 1 post-doc.
  Aims : Role of endosymbionts in Aphids.
  This project is a collaboration with the laboratories of Professors Lognay, Haubruge, Francis Wathelet of the University of Liège and Professor Thonart from the Walloon Center of Industrial Biotechnology. Coordinator Thierry Hance
- WBGREEN, 1.122.170 € (232.000 :Thierry Hance) **Insectech**
  Aims: Technology of insect mass rearing 2013-2014
- PPP, Region Wallonne, Biopsylla, 970.000 €, 2013-2017
  Aims: An analysis of the physiology of psylla nutrition
- PPP Project Région Wallonne, MOUCHE
  Aims: Research of the factors determining the attractiveness of flies (Musca domestica) to various agents to improve control and reduce the amount of insecticides in the barn.200000 euros, Collaboration with Belgagri S.A.. 2014-2016.
- FSR-Marie-Curie, 2013-2015. Optifield
  Aims: Optimal behaviour implementation: from the field complexity to laboratory simplification.
- Beware Academia project : Design of an industrial rearing system of egg parasitoids of moth pests in agriculture. Total budget : 348 840 €, Europe and Wallonia, 2014-2017
- Beware Academia: Chemical communication in domestic housefly. Total budget : 360 000€, Europe and Wallonia, 2016-2019

Curriculum Vitae

Marco Tasin

I am Italian citizen, born in Trento (Italy) on December 19th 1972 and currently resident in Sweden (Vagnvägen 3, 245 63 Hjärup; Swedish Social Personal number: 721219-7151)

My current affiliation is as follow:

Marco Tasin, Associate Professor (Unit Leader)

Department of Plant Protection Biology
Unit of Integrated Plant Protection
SLU, Swedish University of Agricultural Sciences
Box 102
23053 Alnarp, Sweden

E-mail: marco.tasin@slu.se
Tel. (office): +46 40 415268
Tel. (mobile): +46 762 368786

EDUCATION

Ph.D. September 2005
Swedish University of Agricultural Sciences (Alnarp, Sweden), Department of Crop Science, Division of Chemical Ecology. Major: Pheromones and plant volatiles for safe insect control; Minors: Horticulture, Viticulture, Pest Science.

M.S. October 1997
Faculty of Agricultural Sciences, University of Padova, Italy. Department of Entomology. Major: Monitoring tools for pheromone mating disruption; Minors: Horticulture, Modelling, Pest Control.

PROFESSIONAL EXPERIENCE

Current position: Researcher (2012-)

Integrated Plant Protection Division, SLU, Swedish University of Agricultural Sciences, Alnarp, Sweden

2012-2014
In collaboration with the advisory service, the growers, the industry and the researchers, to develop an integrated pest management strategy based on semiochemicals for the control of lepidopteran pests in Swedish apple orchards. Major targets will be the apple fruit moth *Argyresthia conjugella*, the codling moth *Cydia pomonella* and the leafrollers, *Adoxophyes orana*, *Archips podana*, *Archips rosana*, *Pandemis heparana* and *Spilonota ocellana*

Behavioral effect of volatile signals from the habitat background on insect host-selection (*Argyresthia conjugella*)

Financed by SLF, Sweden (project #: H1156188)

2015-2017
Enhancement of pest resiliency in orchards through a synergy between the use of semiochemicals and conservation biological control. Such a strategy aims at keeping pest populations under a damage threshold through the improvement of ecosystem services and the decrease in the use of conventional pesticides. This is expected to promote increasing profits to growers and economic development in rural areas. The effect of the synergy will be focused on aphids, leafrollers and their natural enemies.

Financed by FORMAS (Young Researcher Grant #: brg0313-st2)

Post-doc research fellowships (2005-2010)

IASMA Research and Innovation Center, Foundation Edmund Mach, Italy

Lobesia botrana (field study on the effect of dispenser density on mating disruption efficacy; interaction between grape-born microorganisms and grapevine moth egg-laying females both at an ecological and a pest management level)

Cydia pomonella (behavioural and physiological screening of plant volatiles and sex-pheromones; impact of hail nets on mating disruption in apple orchards; assessing efficacy of mating disruption by release and recapture of males in net-cages)

Argyresthia conjugella (wind tunnel response to host and non-host plant odours; field development of a lure for monitoring based on the rowan odour)

Ostrinia nubilalis (study on the effect of the smell from an ancestral host-plant on assortative meeting; interaction between plant odors and insect sex-pheromone; are

plant odors playing a role in maintaining reproduction isolation in sympatry?)

PhD study (2002-2005)

Chemical Ecology Division, SLU, Swedish University of Agricultural Sciences, Alnarp, Sweden.

Description: Identification of new pheromone compounds and plant volatiles mediating mate and host-finding in grapevine moth. Field and laboratory evaluation of pheromone mating disruption technique. Chemical, electrophysiological and behavioral analysis of vegetative volatiles of grapevine, apple and other host-plants.

Field consultant and trade manager (1999-2001)

Grower Cooperative Society of Bolzano (Italy)
Description: Technical advisor in crop protection and cultivation for grape and apple growers.

Master and technician experience (1994-1999)

IASMA Research and Innovation Center, Foundation Edmund Mach, Italy

Implementation of area wide mating disruption for codling moth control in apple orchards through a participatory research program. In collaboration with the advisory service, the growers and the researchers, I participated in the successfully introduction of the mating disruption technique on a 40 hectares experimental area in the district of Lavis (Trento).

Farm manager and grower (1988-2012)

Description: Management of our family farm. Organic and Integrated Protection of grapevine and apple in Trento (Italy). Cultivation of rootstocks and apple trees.

Scientific reviewing for peer reviewed journals

Scientific Reports
Pest Management Science
Arthropod plant interaction
Journal of Applied Entomology
Entomologia Experimentalis et Applicata
Canadian Entomologist
Journal of Chemical Ecology
Journal of Agricultural and Food Chemistry
Naturwissenshaften
Frontiers in Ecology and Evolution
Journal of Pest Science

Awards

Aldo Gini Foundation, University of Padova (Italy): Grant for a young researcher working outside Italy (2003)

Bioforsk Innovation (Norway): price for the development of a field attractant for the apple fruit moth (2011); patent application 12185428.5-2103 (European Patent Office)

From 2007-2012 I was elected as Convenor of the working group: "Pheromone and other semiochemicals in integrated control", International Organization for Biological Control, Western Paleartic Region (wprs IOBC). The task of this convenorship is to organize biennial meetings within the working group in order to facilitate the exchange of information between scientists and technicians from all over the and actively promote the implementation of Integrated Pest Management into practice. From 2012 I am the deputy Convenor of the working group.

Organization of meetings and conferences

"Semiochemicals without borders", Conference of the working group: "Pheromone and other semiochemicals in integrated production", International Organization for Biological Control (IOBC). Budapest (Hungary), November 9-14 2009. 110 participants.

"Semiochemicals: the essence of green pest control", Conference of the working group: "Pheromone and other semiochemicals in integrated production", International Organization for Biological Control (IOBC). Bursa (Turkey), October 1-5 2012. 105 participants.

Editorial activity

IOBC/wprs Bulletin, Vol. 41, 2009, Working Group "Pheromones and other Semiochemicals in Integrated Production". Proceedings of the meeting at Lund (Sweden), 9 - 14 September 2007. Edited by: Marco Tasin & Peter Witzgall. ISBN 978-92-9067-215-9.

IOBC/wprs Bulletin, Vol. 72, 2012, Working Group "Pheromones and other Semiochemicals in Integrated Production". Proceedings of the meeting at Budapest (Hungary), 9-14 November

2009. Edited by: Marco Tasin, Zsolt Karpati and Miklos Toth. ISSN 1027-3115.

IOBC/wprs Bulletin, Vol. 99, 2014, Working Group "Pheromones and other Semiochemicals in Integrated Production". Proceedings of the meeting at Bursa (Turkey), 1-5 October 2012. Edited by: Marco Tasin and Orkun Baris Kovanci. ISBN 978-92-9067-279-1.

Project management, co-ordination and independently received research funding

Enhancement of pest resiliency in apple orchards through a synergy between semiochemicals and conservation biological control (Tasin Marco, 2015-2017, 5,9 MSek, Formas, Sweden)

Study of the control exerted by natural enemies over aphids and scales in apple orchards and the management factors affecting the natural regulation of pests they provide (Porcel Mario, Tasin Marco, Rämert Birgitta, 2013-2015, 2,7 MSek, SLF, Sweden)

Development of integrated plant protection strategies in apple orchards in co-operation with growers, advisors, pheromone companies and researchers (Tasin Marco, Rämert Birgitta, 2012-2014, 3,0 MSek, SLF, Sweden)

Development of a field lure to monitor the Apple Fruit Moth in Norway (Knudsen Geir, Tasin Marco, Kobro Sverre, 2008-2012, 1,2 MNok, SLF, Norway)

Interplay: on the interaction between microbes and pest (Tasin Marco, 2007-2010, 146000 €, Trento Province, Italy)

Interneuron (Anfora Gianfranco, Mazzoni Valerio, Tasin Marco, Trona Federica, 2009-2010, 310000 €, Trento Province, Italy)

PRIN (DeCristofaro Antonio, Lucchi Andrea, Ioriatti Claudio, Tasin Marco, Anfora Gianfranco, 2006-2008, 90000 €, Italian Ministry of University and Research)

Teaching

I am current teaching in the following courses:

Agroecology Basics (responsible of the course)
Agronomy
Pest Management
Plant protection (I and II)
Urban Agriculture and Social Interactions
Ecology
Environmental issues in plant protection
Ecology of production systems
Research training project
Insect chemical ecology (MSc and PhD course)

Supervision

I co-supervised the PhD student Weronika Swiergiel (dissertation 2016-09-25)

I am currently the main supervisor of the PhD students Joakim Pålsson and co-supervisor of Patrick Sjöberg and Ilich Figueroa

MSc student supervision: Johanna Unger (2014)

Charilaos Chouliaras (current)

BSc student supervision: Cinna Cederlöf (2013)

Therese Diderot (current)

Research training project main supervision: Sherif Mohamed Hassan (2013), Daniele Pasini (2014), Katarina Kovarikova (2015) and Cristina Tha (current).

Centre Wallon de Recherches Agronomiques (CRA-W)

Organization competences:

The Walloon Agricultural Research Centre is a Belgian public research institute that employs today over 430 people among them 120 scientists. This public institution maintains and develops scientific knowledge, skills and excellence for the sustainable development of the agriculture and the whole agro-food sector.
CRA-W has a long experience in Fruit Genetic Resources conservation evaluation and valorization, research on organic fruit production – especially cvs testing for better resilience, strategies for reducing pest and disease spray scheme input, functional biodiversity and alternative orchard designs for better resilience. These trials are followed in experimental orchards integrating eco-system services such as biodiversity, pollination, natural pest control, soil fertility and sustainable disease control strategies, to ensure yield security while minimizing unwanted side-effects. The Research Unit of Plant Breeding & Biodiversity has efficient facilities for evaluation of plant protection products and beneficial organisms including indoors screening bioassays, greenhouses and fully controlled environment climate chambers, field experimentations compliant with EPPO standardsSeveral hectares of experimental orchards are currently managed and unsprayed evaluation orchards are available for pest resistance assessments.

Key persons involved:

Dr. Marc Lateur (m), senior scientist, head of Plant Breeding & Biodiversity Unit and of the Fruit Genetic Resources & Breeding team. He is specialized in the evaluation of fruit cultivars for pest & disease resistance/tolerance, he is the current chairman of the ECPGR Working Group for *Malus & Pyrus* genetic resources; he is managing the fruit tree genetic resources collection, is leading apple and pear breeding programs and different research projects. Active member of the participative research group “Vergers + Durables” led by INRA Avignon (FiBL, SERIDA, IFPC, GRAB, CRA-W), bringing together scientists, advisors and growers.

Dr. Laurent Jamar (m), senior scientist, project manager. He developed scientific knowledge's and specific expertise in research for sustainable and organic agricultural systems (e.g. set-up of sustainable agroecosystems, biological controls, functional biodiversity applications and assessments, methodological expertise for pest and disease control studies, diseases identifications, environmental impact studies, life cycle analysis, ecological balance sheets, cultivars selections. He achieved numerous publications in specialized journals and various communications during scientific symposia. Active member of the participative research group “Vergers + Durables” led by INRA Avignon (FiBL, SERIDA, IFPC, GRAB, CRA-W), bringing together scientists, advisors and growers. Partner of the INTERREG IV "TransBioFruit" and of a CRA-W project dealing with research in organic fruit growing systems; currently partner. From 2015, he is partner of the Eranet Core Organic Plus “Eco-orchard” project.

Relevant publications

- Wateau K., Tournant L., Jamar L. (2009). Décoction de *Quassia amara* et lutte contre l’hoplocampe du pommier (*Hoplocampa testudinea* Klug). Actes des Journées Techniques Nationales Fruits et Légumes Biologiques, ITAB-GRAB, Paris, 8 & 9 décembre 2009, 25-30.
- Bellon S., Fauriel J., Hemptine J.-L., Jamar L., Lauri P.E., Lateur M., Libourel G., Simon S. (2009). Eco-design and Co-design: application to fruit production in Europe. The Second Farming Systems Design Symposium, Monterey (USA), August 23 to 26, 2009, pp. 29-30.
- Kellerhals M, Szalatnay M, Hunziker K, Duffy B, Nybom H, Ahmadi-Afzadi M, Höfer M, Richter K, Lateur M (2012). European pome fruit genetic resources evaluated for disease resistance. Trees 26, 179-189.

- Parisi, L., Jamar, L., Lateur, M., Laurens, F., Lauri, P.E. (2014). Adapting apple ideotypes to low-input fruit production agro-ecosystems. *In* Organic Farming, Prototype for Sustainable Agriculture. S. Bellon, Penvern S. (eds.), Springer, Doordrecht, 131-148.
- Wateau K., Tournant L., Jamar L., Oste S. (2011). Les ravageurs secondaires en verger de production biologique : recherche de nouvelles techniques de lutte contre *Hoplocampa testudinea* Klug et *Anthonomus pomorum* Linnaeus. AFPP - 4ème Conférence Internationale sur les Méthodes Alternatives en Protection des Cultures, 8, 9 & 10 mars 2011, Lille, France, pp. 535-545.
- Jamar L., Lateur M., Tournant L., Wateau K., Dewaegeneire P., Oste S., Montignies E., Thiran B., Delebecq A., Fitoussi J. (2016). Les principales clès du verger bio transfrontalier – Pommes et poires, une approches globale. Ed. Interreg IV TransBioFruit, pp. 84

Relevant projects

- ERANET- CORE ORGANIC +, “ECO-ORCHARD”: Innovative design and management to boost functional biodiversity of organic orchards; Coordinator: Lene Sigsgaard (DK); Countries involved: DK, FR, CH, SE, IT, DE, BE, PL & LV; 2015-2017.
- FruitBreedomics: EU FP7-KBE-2010-4-#265582 “Integrated approach for increasing breeding efficiency in fruit tree crops’’; 2011-2015
- INTERREG Trans-border project TRANSBIOFRUIT “Trans-border cooperation on organic top fruit production. (together with North-France); 2011-2015.

Organization competence

General Description: IRTA is a public research institution, part of the Department of Agriculture, Food and Rural Action of the regional Government of Catalonia, Spain. IRTA's mission is to contribute to modernising, improving and boosting competitiveness, and fostering sustainable development in the sectors of, agriculture, animal and plant production, food technology, agroforestry, aquaculture, fisheries, the agro-food economy, and environment and global change, with the aim of consolidating a sustainable bio-based economy. Other areas of activity are those which are directly or indirectly related to the supply of healthy, high-quality foodstuffs to end consumers, food safety and safe processing of foodstuffs and in general enhancing the health and well-being of the population.

The research team belongs to the IRTA Fruit Program that is devoted to fruit, olive and nut production. R+D+T activities are grouped in plant material, crop technology, product quality, and environmentally friendly techniques for fruit production. Regarding environmentally friendly techniques for fruit production, this research team worked on: evaluation of apple resistant varieties and rootstocks to pests and diseases, non-chemical techniques to control fruit set, organic and integrated pest, diseases and weed management and in improving biodiversity as a key to enhance biological control.

Key persons

Dr. Georgina Alins

Dr. Alins (Agronomist, University of Lleida) carried out the first Spanish PhD in organic apple production and has more than 10 years of experience in organic apple management, crop protection, ecological infrastructures, and evaluation of plant material. She has participated in 3 EU projects, 5 national projects and 8 private contracts. She published 4 SCI papers, more than 20 technical papers and she has contributed with poster and oral presentations in about 40 national and international congresses. She supervised 1 PhD student and 2 master students.

Dr. Simó Alegre

Agricultural engineer (University of Lleida) with more than 20 years dedicated to fruit tree research. He is the chief of the Fruit Program of IRTA (10 Ph.D. Scientists, 31 technical staff and 2 Ph.D students). Dr. Alegre has participated in 18 Spanish and 9 European projects related to fruit quality, growing techniques, and organic agriculture. In these projects he has carried out scientific and administrative tasks, and has been involved in management committees. He has participated in 9 EU projects, 17 national projects, 56 private contracts and 18 patents. He published 20 SCI papers and about 90 technical papers and he has contributed with poster and oral presentations in about 50 national and international congresses. He has supervised 4 PhD students.

Relevant publications

Lordan J, S Alegre, R Moerkens, MJ Sarasua, G Alins. 2015. Phenology and interspecific association of *Forficula auricularia* and *Forficula pubescens* in apple orchards. Spanish Journal of Agricultural Research 13(1). 10.5424/sjar/2015131-6814.

Lordan J, S Alegre, F Gatius, M-J Sarasua, G Alins. 2015. Woolly apple aphid *Eriosoma lanigerum* Hausmann ecology and its relationship with climatic variables and natural enemies in Mediterranean areas. Bulletin of Entomological Research 105(1):60-69. 10.1017/s0007485314000753.

Alins G, N Rodríguez-Gasol, S Alegre, J Lordan, Y Aparicio, R Gabarra, M Artigues, J Arnó. 2015. Infraestructuras ecológicas en frutales: un cambio de paradigma. Horticultura 319:16-19.

Lordan J, S Alegre, R Blanco, MJ Sarasua, G Alins. 2014. Aggregation behavior in the European earwig: Response to impregnated shelters. Crop Protection 65:71-76. 10.1016/j.cropro.2014.07.005.

Lordan J, S Alegre, G Alins, MJ Sarasua, A Morton, F Garcia del Pino. 2014. Compatibility between *Forficula auricularia* and entomopathogenic nematodes to be used in pome fruit pest management. Journal of Applied Entomology 138(9):635-643. 10.1111/jen.12118.

Lordan J, G Alins, M-J Sarasúa. 2012. Diversity and abundance of spiders in the flora of the fruit area around Lleida (NE Spain). IOBC/WPRS Bulletin 75:123-126.

Relevant projects

RED BIO: “Red de Experimentación, de intercambios y de transferencia para el desarrollo de la agricultura ecológica en producciones vegetales a destinación de agricultores catalanes”. Interreg IVA EFA 10/08 RED BIO. 2009-2011.

INIA RTA 2010-00121-C02-01. “Mejora de sistemas de producción de manzana en agricultura ecológica”. 2010-2013.

FruitBreedomics: “Integrated approach for increasing breeding efficiency in fruit tree crops’’. FP7-KBBE, 265582, 2011-2015.

EFFIDRIP: “Enabling next generation commercial service-oriented, automatic irrigation management systems for high efficient use of water, fertilizers and energy in drip irrigated tree crops”. FP7-SME, 286807. 2012-2014.

ECO-ZEO: "Developing a pool of novel and eco-efficient applications of zeolite for the agriculture sector". FP7-ENV, 282865, 2012-2016.

AGL2013-49164-C2 Control Integrado de Plagas en Cultivos Hortofrutícolas. 2014-2016.

Participant Profile

SERIDA – Villaviciosa, Asturias, Spain

Public Research Institute

www.serida.org

General Description of the organisation

The Regional Institute for Research and Agro-Food Development (SERIDA) is a public organism of the Principality of Asturias (Spain) with its own legal personality, which was created through Asturian Law 5/1999. It carries out the agrarian and agrofood research programs within the Ministry of Livestock Farming and Natural Resources of the Government of the Principality of Asturias. SERIDA aims to contribute to the modernization and improvement of the capacities of the regional agro-food sector by promoting and carrying out research and technological development and innovation in order to improve productivity, profitability, diversity and competitiveness of Asturian agrofood sector, and increase returns on primary assets by the adequacy production systems that respect environment and also the marketing structure for high quality products

The SERIDA participates in the project through the Fruit Research Unit, whose main lines of work are:

- Conservation, characterisation and analysis of the genetic diversity of the apple and other fruit species.
- Evaluation, selection and breeding of apple cultivars for improvement of the resistance (rosy apple aphid, scab, …), regular bearing and fruit quality. Studies on the plant – bio-aggressor relationship.
- Development of organic production systems in apple and other fruit trees adapted to local conditions.
- Sustainable plant protection, Interaction soil-tree, pollination and regulation of production.

Key persons involved

Dr. Enrique Dapena (m) studied Biology at the University of Oviedo until 1979. In 1996 he obtained his PhD degree with a research on "Agronomical and technological evaluation of Asturian apple cultivars" Since 1979 to 1982 he worked as part of a rural development plan, conducting a study to improve the cultivation of apple cider in a municipality of the cider shire. In 1985-1986 he made a research stay at INRA Rennes on technological evaluation of cider apple and cider making process and at INRA of Angers on breeding program of apple. In 1986 started to work as scientist in CEA (now SERIDA). Since 1989 to 1995 he was head of Cider Apple Program, since 1990 he is Curator of Apple Gene Bank and since 2006 he is head of Fruit Research Unit of the SERIDA. He has coordinated 32 national projects of research on genetic resources and breeding program of apple and improvement of apple production system and organic production adapted to local conditions, he has participated in two European projects, a Interreg SUDOE project "ECOVERGER" on extensive system of production in fruit orchards and in FruitBreedomic project. He has been the author of 34 scientific papers, three books and seven book chapters, 65 communications to congress and more 90 technical publications. Also he has coordinated and participated in numerous technical conferences and courses for technicians and growers…

Dr. Marcos Miñarro (m) studied Biology at the University of Oviedo until 1997. Since 1998 to 2002 he had a pre-doctoral grant to research in SERIDA and received his PhD degree at the same University of Oviedo in 2006. Since 2003 is working as researcher in SERIDA at the Fruit Research Unit. He is specialized in the study and development of apple production systems adapted to local conditions and to organic production and, more specifically, in plant protection. He worked extensively on

biological control and plant-pest interaction for sustainable control of several apple pests, such as the rosy apple aphid, codling moth or spider mites. He also works on the role of landscape and management on the biodiversity of pollinators and natural enemies and finally on the services of pollination and pest control.

Relevant publications and projects

Publications

Pagliarani, G., Dapena, E., Miñarro, M., Denancé, C., Lespinasse, Y., Rat-Morris, E., Troggio, M., Durel, C.E., Tartarini, S. (2016). Fine mapping of the rosy apple aphid resistance locus Dp-fl on linkage group 8 of the apple cultivar 'Florina'. Tree Genetics and Genomes (in press). DOI: 10.1007/s11295-016-1015-x.

Rosa-García, R., Miñarro, M. (2014). Role of floral resources in the conservation of pollinators in cider apple orchards. Agriculture, Ecosystems and Environment 183: 118-126.

Miñarro, M., Prida, E. (2013). Hedgerows surrounding organic apple orchards in north-west Spain: potential to conserve beneficial insects. Agricultural and Forest Entomology 15: 382-390

Miñarro, M. (2012). Weed communities in apple orchards under organic and conventional fertilization and tree-row management. Crop Protection 39: 89-96.

Miñarro, M., Fernández-Mata, G., Medina, P. (2010). Role of ants in structuring the aphid community on apple. Ecological Entomology 35: 206-215.

Miñarro, M., Dapena, E. (2010). Multitrophic effects of organic fertilization and tree-row management in cider-apple orchards. Proceedings of the 14th International Conference on Organic Fruit-Growing, 285-291.

Miñarro, M., Espadaler, X., Melero, V.X., Suárez-Álvarez, V. (2009). Organic versus conventional management in an apple orchard: effects of fertilization and tree-row management on ground-dwelling predaceous arthropods. Agricultural and Forest Entomology 11: 133-142.

Miñarro, M., Dapena, E. (2008). Tolerance of some scab-resistant apple cultivars to the rosy apple aphid, *Dysaphis plantaginea*. Crop Protection 27: 391-395.

Miñarro, M., Dapena, E. (2007). Resistance of apple cultivars to *Dysaphis plantaginea* (Hemiptera: Aphididae): role of tree phenology in infestation avoidance. Environmental Entomology 36(5): 1206-1211.

Miñarro, M., Hemptinne, J-L., Dapena, E. (2005). Colonization of apple orchards by predators of *Dysaphis plantaginea*: sequential arrival, response to prey abundance and consequences for biological control. Biocontrol 50 (3): 403-414.

Miñarro, M., Dapena, E. (2003). Effects of groundcover management on ground beetles (Coleoptera: Carabidae) in an apple orchard. Applied Soil Ecology 23: 111-117.

Projects

2015-2018. INIA RTA2014-00090-C03. Breeding new table apple varieties for fruit quality and biotic resistance. Molecular marker assisted selection. Coord.: Dr. E. Dapena

2014-2017. BiodivERsA-FACCE2014-74. Managing biodiversity for fruit production in different European climates (EcoFruit). Coord.: A-M. Klein

2014-2017. INIA RTA2013-00039-C03-01. Ecosystem services of pollination and pest control in woody crops: effects of landscape and management. Coord.: M. Miñarro

2010-2014. INIA RTA2010-00121-C02-01. Improving apple production systems in organic farming. Coord.: M. Miñarro.

2007-2009. FICYT PC07-23. Mejora de los sistemas de cultivo para lograr una producción sostenible de manzana de calidad. Coord.: E. Dapena.

2006-2008. INIA RTA-2006-00156-00-00 Defensa vegetal y manejo de arvenses en producción ecológica de manzana de calidad. Coord.: E. Dapena.

References list (references cited in the background section and the work plan of the present project)

Please note: Main references of partners related to the present project are listed below with partner information

Alaphilippe A., Angevin F., Guérin A., Guillermin P., Vélu A., Zavagli F., 2015. DEXiFruits: an easy-to-use tool to evaluate the sustainability of fruit productions system. ISHS International Symposium INNOHORT: Innovation in Integrated and Organic Horticulture, 8-12 June 2015, Avignon (FRA). Book of abstracts, p. 51. http://wiki.inra.fr/wiki/deximasc/DEXiFruits/1-+Accueil

Amarawardana L., Bandara P., Kumar V., Pettersson J., Ninkovic V., Glinwood R., 2007. Olfactory response of *Myzus persicae* (Homoptera: Aphididae) to volatiles from leek and chive: Potential for intercropping with sweet pepper. Acta Agric Scand Sect B Soil Plant Sci 57:87-91.

Baggiolini M., Favre G., Fiaux G., 1973. Integrated and directed control in orchards. Ten years of experiments in pilot crops in the Leman Valley, Rev suisse Vitic Arboric Hortic 5(3):83–90.

Barbaro L., Giffard B., Charbonnier Y., Halder I., Brockerhoff E.G., 2014. Bird functional diversity enhances insectivory at forest edges: a transcontinental experiment. Diversity and Distributions 20(2):149-159.

Ben Issa R., Gautier H., Gomez L., 2016. Which companion plants can affect the performance of green peach aphid on host plants? Screening of thirteen candidate plants under laboratory conditions. Entomol Exp Appl, in press.

Boreau de Roincé C., Lavigne C., Mandrin J.F., Rollard C., Symondson W.O.C., 2013. Early-season predation on aphids by winter-active spiders in apple orchards revealed by diagnostic PCR. Bulletin of Entomological Research 103:148-154.

Boreau de Roincé C., Lavigne C., Ricard J.-M., Franck P., Bouvier J.-C., Garcin A., Symondson W.O.C., 2012. Predation by generalist predators on the codling moth versus a closely-related emerging pest the oriental fruit moth: a molecular analysis. Agricultural and Forest Entomology 14:260-269.

Borowiec N., Muru D., Malausa T., Ris N., 2016. Document technique relatif à l'introduction dans l'environnement de l'hyménoptère parasitoïde exotique, *Mastrus ridens*. Dossier soumis pour évaluation par la DGAL et l'ANSES, 34 p.

Breda N., Huc R., Granier A., Dreyer E., 2006. Temperate forest trees and stands under severe drought: a review of ecophysiological responses, adaptation processes and long-term consequences. Ann For Sci 63:625–644.

Brown M.W., 1999 Applying principles of community ecology to pest management in orchards. Agriculture, Ecosystems & Environment 73:103-106.

De Almeida J., 2012. Aménagement d'une plate-bande de fleurs pour améliorer la lutte naturelle de deux ravageurs du pommier, *Hoplocampa testudinea* (Tenthredinidae) et *Aphis pomi* (Aphididae). Mémoire de Maîtrise en Biologie, Université du Québec, Montréal.

Dib H., Simon S., Sauphanor B., Capowiez Y., 2010. The role of natural enemies on the population dynamics of the rosy apple aphid, *Dysaphis plantaginea* Passerini (Hemiptera: Aphididae) in organic apple orchards in south-eastern France. Biological Control 55:97-109.

Dib H., Sauphanor B., Capowiez Y., 2016. Effect of management strategies on arthropod communities in the colonies of rosy apple aphid, *Dysaphis plantaginea* Passerini (Hemiptera: Aphididae) in south-eastern France. Agriculture, Ecosystems & Environment 216:203–206.

Dumont V.A., Trigaux A., Moreau A., Hance T., 2011. Study of two conditioning methods of parasitoids used in biological control prior to inundative releases in apple orchards. European Journal of Environmental Sciences 1(1).

Eurostat, 2014. http://ec.europa.eu/eurostat/statistics-explained/index.php/Agricultural_production_-_orchards#Apple_trees (accessed 16 September 2016)

Grechi I., Sauge M.H., Sauphanor B., Hilgert N., Senoussi R., Lescourret F., 2008. How does winter pruning affect peach tree - *Myzus persicae* interactions? - Entomol Exp Appl 128:369-379.

Gurr G.M., Van Emde H.F., Wratten S.D., 1998. Habitat manipulation and natural enemy efficiency: implications for the control of pests, pp. 155-183. In: Barbosa P. (ed) Conservation biological control, Springer.

Hale B.K., Bale J.S., Pritchard J., Masters G.J., Brown V.K., 2003. Effects of host plant drought stress on the performance of the bird cherry-oat aphid, *Rhopalosiphum padi* (L.): a mechanistic analysis. Ecological Entomology 28(6):666-677.

Heijne B., Helsen H.H.M., Caffi T., Rossi V., Strassemeyer J., Khöl J., Riemens M.M., Alaphilippe A., Simon S., Capowiez Y., Holb I.J., Buurma J.S., Hennen W.H.G.J., 2015. PURE progress in innovative IPM in pome fruit in Europe. Acta Horticulturae 1105:283-289.

Jordan M.O., Vercambre G., Gomez L., Pagès L., 2014. The early spring N uptake of young peach trees (*Prunus persicae*) is affected by past and current fertilisations and levels of C and N stores. Tree Physiol 34:61–72.

Knuff A.K., Obermaier E., Mody K., 2016. Differential susceptibility and suitability of domestic and wild apple species for a florivorous weevil and its parasitoids. Journal of Applied Entomology. In press.

Kuhlmann U., Mills N.J., 1999. Exploring the diversity of Central Asia to assess specialized parasitoids for biological control of apple pests in Europe and North America. IOBC/WPRS Bulletin 22:1-6.

Landis D.A., Wratten S.D., Gurr G.M., 2000. Habitat management to conserve natural enemies of arthropod pests in agriculture. Annu. Rev. Entomol. 45:175–201.

Lauri P.É., Simon S., Navarrete M., Parrot L., Normand F., Lesueur-Jannoyer M., Deguine J.P., 2016. Multidisciplinary and multiagent interactions for innovations in horticulture – Paradigms beyond the words. Acta hortic. 1137:255-265.

Le Bellec F., Rajaud A., Ozier-Lafontaine H., Bockstaller C., Malézieux É., 2012. Evidence for farmer's active involvement in co-designing citrus cropping systems using an improved participatory method. Agronomy for Sustainable Development 32:703-714.

Letourneau D.K., Jedlicka J.A., Bothwell S.G., Moreno C.R., 2009. Effects of natural enemy biodiversity on the suppression of arthropod herbivores in terrestrial Ecosystems. Annual Review of Ecology, Evolution and Systematics 40:573-592.

Lordan J., Alegre S., Gatius F., Sarasua M.-J., Alins G., 2015. Woolly apple aphid *Eriosoma lanigerum* Hausmann ecology and its relationship with climatic variables and natural enemies in Mediterranean areas. Bulletin of Entomological Research 105(1):60-69.

MAAF 2012. MAAF Ministry of Agriculture, Agrifood and Forest, 2015. http://agriculture.gouv.fr/sites/minagri/files/151022_ecophyto.pdf (accessed on 30 October 2015).

Maalouly M., Franck P., Bouvier J.-C., Toubon J.-F., Lavigne C., 2013. Codling moth parasitism is affected by semi-natural habitats and agricultural practices at orchard and landscape levels. Agriculture, Ecosystems & Environment 169:33-42.

Maalouly M., Franck P., Lavigne C., 2015. Temporal dynamics of parasitoid assemblages on the codling moth. Biological control 82:31-39.

Mace K.C., Mills N.J., 2015. Response of walnut aphid populations to increasing foliar nitrogen content. Agricultural and Forest Entomology 17:277-284.

Malézieux E., 2012. Designing cropping systems from nature. Agronomy for Sustainable Development 32:15-29.

Marliac G., Simon S., Mazzia C., Penvern S., Lescourret F., Capowiez Y., 2015. Increased grass cover height in the alleys of apple orchards does not promote *Cydia pomonella* biocontrol. BioControl 60:805-815.

Matis T.I., Parajulee M.N., Matis J.H., Shrestha R.B., 2008. A mechanistic model based analysis of cotton aphid population dynamics data. Agricultural and Forest Entomology 10:355-362.

Mills N.J., 2005. Selecting effective parasitoids for biological control introductions: Codling moth as a case study. Biological Control 34:274-282.

Miñarro M., Hemptinne J-L., Dapena E., 2005. Colonization of apple orchards by predators of *Dysaphis plantaginea*: sequential arrival, response to prey abundance and consequences for biological control. Biocontrol 50 (3):403-414.

Miñarro M., Dapena E., 2007. Resistance of apple cultivars to *Dysaphis plantaginea* (Hemiptera: Aphididae): role of tree phenology in infestation avoidance. Environmental Entomology 36(5):1206-1211.

Miñarro M., Fernández-Mata G., Medina P., 2010. Role of ants in structuring the aphid community on apple. Ecological Entomology 35:206-215.

Mody K., Collatz J., Dorn S., 2015. Plant genotype and the preference and performance of herbivores: cultivar affects apple resistance to the florivorous weevil *Anthonomus pomorum*. Agricultural and Forest Entomology 17(4):337-346.

Mols C.M., Visser M.E., 2002. Great tits can reduce caterpillar damage in apple orchards. Journal of applied ecology 39(6):888-899.

Ostman O., 2004. The relative effects of natural enemy abundance and alternative prey abundance on aphid predation rates. Biol. Control 30:281–287.

Oswald C.J., Brewer M.J., 1997. Aphid-barley interactions mediated by water stress and barley resistance to Russian wheat aphid (Homoptera: Aphididae). Environmental Entomology 26:591-602.

Pagliarani G., Dapena E., Miñarro M., Denancé C., Lespinasse Y., Rat-Morris E., Troggio M., Durel C.E., Tartarini S., 2016. Fine mapping of the rosy apple aphid resistance locus Dp-fl on linkage group 8 of the apple cultivar 'Florina'. Tree Genetics and Genomes 12:56.

Parolin P., Bresch C., Brun R., Bout A., Boll R., Desneux N., Poncet C., 2012. Secondary plants used in biological control: a review. International Journal of Pest Management 58:91-100.

Pickett J., Wadhams L., Woodcock C., Hardie J., 1992. The chemical ecology of aphids. Annual Review of Entomology 37:67-90.

Pons X., Tatchell G.M., 1995. Drought stress and cereal aphid performance. Annals of applied biology 126:19-31.

Ratnadass A., Fernandes P., Avelino J., Habib R., 2012. Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: a review. Agronomy for Sustainable Development 32:273-303.

Sauge M.H., Grechi I., Poëssel J.L., 2010. Nitrogen fertilization effects on *Myzus persicae* aphid dynamics on peach: vegetative growth allocation or defensive chemistry effects? Entomol Exp Appl 136:123-133.

Sigsgaard L., 2010. Habitat and prey preferences of the two predatory bugs *Anthocoris nemorum* (L.) and *A. nemoralis* (Fabricius) (Anthocoridae: Hemiptera-Heteroptera). Biological Control 53:46-54.

Simon S., Bouvier J.C., Debras J.F., Sauphanor B., 2010. Biodiversity and pest management in orchard systems. A review. Agronomy for Sustainable Development 30:139-152.

Simon S., Morel K., Durand E., Brevalle G., Girard T., Lauri P.E., 2012. Aphids at crossroads: when branch architecture alters aphid infestation patterns in the apple tree. Trees, 26(1):273-282.

Simon S., Lesueur-Jannoyer M., Plénet D., Lauri P.É., Le Bellec F., 2016. Methodology to design agroecological orchards: Learnings from on-station and on-farm experiences. European Journal of Agronomy (in press). http://dx.doi.org/10.1016/j.eja.2016.09.004.

Stewart-Jones A., Pope T.W., Fitzgerald J.D., Poppy G.M., 2008. The effect of ant attendance on the success of rosy apple aphid populations, natural enemy abundance and apple damage in orchards. Agric. For. Entomol. 10:37–43.

Symondson W.O.C., Sunderland K.D., Greenstone M.H., 2002. Can generalist predators be effective biocontrol agents? Annual Review of Entomology 47:561-594.

Veres A., Petit S., Conord C., Lavigne C., 2013. Does landscape composition affect pest abundance and their control by natural enemies? A review. Agriculture, Ecosystems & Environment 166:110-117.

Zehnder G., Gurr G.M., Kühne S., Wade M.R., Wratten S.D., Wyss E., 2007. Arthropod pest management in organic crops. Annu Rev Entomol 52:57–80.

Appendix 1. Partner planned activities on specific levers

Partner (contact person, institution, country)	**Target insects**	**Processes & measures** (number)	**Type of experiment** (on-station/ on-farm)	**Details**
P1. A. Alaphilippe, Sylvaine Simon, INRA Gotheron, France	Rosy Apple Aphid All pests present in South of France	1, 2, 4, 5, 6 4, 6	On-station, 5 experimental orchards (2 ha) Experimental hedgerows	Companion plants (among which rosemary): assessment of the repulsive/disruptive effect on aphids; ant diversion Test of a control strategy integrating most processes in field condition Orchard design
P1. Claire Lavigne, Hélène Gautier, Pierre Franck, Laurent Gomez, M.-Odile Jordan, Myriam Siegwart, INRA PSH, France	Rosy Apple Aphid Codling moth	1, 3, 4	French orchards above described	Shared simplified protocol to assess the effect of tree growth on the development of aphid colonies Estimation of pest suppression using sentinel preys (aphids and eggs) + PCR analyses of gut content Simplified description of the arthropod community Measures of VOC emitted by companion plants
P1. Nicolas Borowiec, Elodie Vercken, INRA ISA, France	Codling moth	6	On farm experiment (network of 4-5 farms)	Mass release of parasitoïds
P2. Lene Sigsgaard, Stine Kramer, UCPH, Denmark	Aphid complex Codling moth	4, 6	On-station, on farm (network of 8-10 farms)	Flower strips and hedge as sources of predators Bioassays of predators for mass-release against aphids
P3. CE Parveaud, Johanna Brenner, GRAB, France	Sawfly Insect pests of organic orchards	1, 6 3, 4	On- station and on-farm experiment	Using diffusers of essential oil used as repulsive/disruptive volatile organic compounds Measures to discourage pest development

P4. Thierry Hance, S. Demeter, UC Louvain, Belgium (Wallonie)	Rosy apple aphid	4, 6	On station experiments	Mass release of two parasitoid species, *Ephedrus cerasicola* and *Aphidius matricariae* and one predator *Aphidoletes aphidimyza*
P5. Marco Tasin, SLU, Sweden	Aphid complex and tortricid moths	1, 2, 4, 5, 6	On-station (2 plots) and on-farm experiment (network of 8 farms)	Ant diversion Introduction of trap plants
P6. Marc Lateur; Laurent Jamar, CRA-W, Belgium (Wallonie)	Rosy apple aphid Codling moth	1, 2, 3, 4 6	On-station experiments	Assessment of cultivar susceptibility, work on possible trap plant and/or dilution effect Population monitoring Work on mass trapping (trapping system with light)
P7. Georgina Alins, IRTA, Spain	Aphids, including rosy apple aphid	4, 5, 6	On farm experiment (network of 8 farms)	Effect of flower strips, diversion of ants and introduction of shelters for earwigs on aphid colonies
P8. Enrique Dapena, Marcos Miñarro, SERIDA, Spain	Aphids, including rosy apple aphid Codling moth	3, 4 4	On station experiments On farm	- Effect of cultivars, rootstock and cropping system - Role of landscape, hedges & ground cover on aphid predator Role of birds

Appendix 2. Person.month breakdown

	Country	General activities & management	WP1	WP2	WP3	WP4	Total	Comment
Sub-total INRA Gotheron	*France*	*3.5*	*3.3*	*4.5*	*2*	*8*	*21.3*	+Trainees 30 p.m.:
Sub-total INRA PSH	*France*	*1*	*1*	*2*	*4.9*	*1*	*9.9*	1 p.m. on WP1; 5 p.m. on
Sub-total INRA ISA	*France*	*0.6*	*0.1*	*0.6*	*3*	*0.1*	*4.4*	WP2; 22 p.m. on WP3;
P.1 TOTAL INRA	**France**	**5.1**	**4.4**	**7.1**	**9.9**	**9.1**	**35.6**	2 p.m. on WP4
P2. University of Copenhagen	**Denmark**	**0.75**	**0.5**	**0.5**	**17.5**	**0.25**	**19.5**	
P3. GRAB	**France**	**0.75**	**0.75**	**3.25**	**3.5**	**0.75**	**9**	+ Trainees: 6 p.m. on WP3
P4. Université Catholique de Louvain	**Belgium (Wallonie)**	**0.5**	**2**	**1**	**7**	**0.2**	**10.7**	
P5. Swedish University of Agricultural Science	**Sweden**	**1**	**1**	**16**	**5**	**1**	**24**	
P6. Centre Wallon de Recherche Agronomiques	**Belgium (Wallonie)**	**0.5**	**1.5**	**1.6**	**6.9**	**0.2**	**10.7**	
P7. Institut de Recerca i Tecnologia Agroalimentaries	**Spain**	**1**	**2**	**5.5**	**12.25**	**2**	**22.75**	
P8. Servicio regional de Investigacion y Desarrollo Agroalimentario	**Spain**	**1**	**1.5**	**1.5**	**15**	**0.2**	**19.2**	
TOTAL Project		**10.6**	**13.65**	**36.45**	**77.05**	**13.7**	**151.45**	+ Trainees 36 p.m.

Appendix 3. Partner skills & expertise, relevant publications

Skills / Partner	Entomology			Chemical ecology		Agronomy		Multicriteria assessment		Other	Publications
	Pest control	Natural enemies	Taxonomy	Insect behaviour	VOCs identification	Tree Physiology	Production system	Efficacy & costs	Sustainability		
P1. INRA Gotheron	**X**	**X**	**X** (functional groups)			**X** (tree architecture)	**X**	**X**	**X**		Simon et al. 2010 ; 2012 ; 2016 Alaphilippe et al. 2008 ; 2016
P1. INRA PSH	**X** mass rearing	**X**		**X** (tunnel)	**X**	**X** (tree nutrition)				X Landscape	Maalouly et al. 2015 Veres et al. 2013 Boreau de Roincé et al. 2013 Maalouly et al. 2013 Dib et al. 2010
P1. INRA ISA	**X** mass rearing	**X**	**X**							X Landscape	Zboralski et al. 2016 Borowiec et al. 2016
P2. UCPH	**X**	**X**	**X**								Sigsgaard et al. 2006 Sigsgaard 2010 Sigsgaard et al. 2013
P3. GRAB	**X**	**X**					**X**				Parveaud et al. 2014 Parisi et al. 2013 Gomez et al. 2012 Dib et al. 2012
P4. UC Louvain	**X**	**X**		**X**						Modelisation (DSS tool)	Hance et al. 2007 Stilmant et al. 2008 Dumont et al. 2011 Boivin et al. 2012 Nicolas et al. 2015
P5. SLU	**X**	**X**	**X**	**X**			**X**				Porcel et al. 2015 Sjöberg at al. 2015 Knudsen et al. (2015)
P6. CRA-W	**X**	**X**					**X**				Wateau et al. 2009 Bellon et al. 2009 Kellerhals et al. 2012 Parisi et al. 2014 Wateau et al. 2011 Jamar et al. 2016

P7. IRTA	**x**	**x**				**X** (tree architecture)	**x**				Lordan et al. 2014a Lordan et al. 2014b Lordan et al. 2015a Lordan et al. 2015b
P8. SERIDA	**X**	**X**				**X**	**X**				Rosa Garcia et al. 2014 Miñarro et al. 2003-2013

Cited references

Alaphilippe A., Elad Y., Rav david D., Derridj S., Gessler C., 2008. Effects of a biocontrol agent of apple powdery mildew (*Podosphaera leucotricha*) on the host plant and on non-target organisms: an insect pest (*Cydia pomonella*) and a pathogen (*Venturia inaequalis*). Biocontrol Science and Technology 18(1-2):121-138. Doi: 10.1080/09583150701818964

Alaphilippe A., Boissy J., Simon S., Godard C., 2016. Environmental impact of intensive versus semi-extensive apple orchards: use of a specific methodological framework for Life Cycle Assessments (LCA) in perennial crops. Journal of Cleaner Production 127:555-56. Doi:10.1016/j.jclepro.2016.04.031

Bellon S., Fauriel J., Hemptine J.-L., Jamar L., Lauri P. É., Lateur M., Libourel G., Simon S., 2009. Eco-design and Co-design: application to fruit production in Europe. The Second Farming Systems Design Symposium, Monterey (USA), 23-26 August 2009, pp. 29-30.

Boivin G., Hance T., Brodeur J., 2012. Aphid parasitoids in biological control. Can. J. Plant Sci. 92:1-12.

Boreau de Roince C., Lavigne C., Mandrin J. F., Rollard C., Symondson W. O. C., 2013. Early-season predation on aphids by winter-active spiders in apple orchards revealed by diagnostic PCR. Bulletin of Entomological Research 103:148-154.

Borowiec N., Muru D., Malausa T., Ris N., 2016. Document technique relatif à l'introduction dans l'environnement de l'hyménoptère parasitoïde exotique, *Mastrus ridens*. Dossier soumis pour évaluation par la DGAL et l'ANSES, 34 p.

Dib H., Simon S., Sauphanor B., Capowiez Y., 2010. The role of natural enemies on the population dynamics of the rosy apple aphid, *Dysaphis plantaginea* Passerini (Hemiptera: Aphididae) in organic apple orchards in south-eastern France. Biological Control 55:97-109.

Dib H., Libourel G., Warlop F. 2012. Entomological and functional role of floral strips in an organic apple orchard: Hymenopteran parasitoids as a case study. Journal of Insect Conservation 16:315–318.

Dumont V.-A., Trigaux A., Moreau A., Hance T., 2011. Study of two conditioning methods of parasitoids used in biological control prior to inundative releases in apple orchards. European Journal of Environmental Sciences 1(1):51–56

Gomez C., Parveaud CE., Libourel G., Romet L., Warlop F., Brun L., Simon S., Pouzoulet D., Delebecq A., Laurens F., Oste S., Tournant L., 2012. Sensibilité variétale aux maladies et ravageurs. Anciennes et nouvelles variétés en AB : Puceron cendré du pommier. Fiche n°7. Arboriculture Fruitière, mars 2012.

Hance T., van Baaren J., Vernon P. , Boivin G., 2007. Impact of extreme temperatures on parasitoids in a climate change perspective. Annual review of Entomology, 52:107-126.

Jamar L., Lateur M., Tournant L., Wateau K., Dewaegeneire P., Oste S., Montignies E., Thiran B., Delebecq A., Fitoussi J., 2016. Les principales clés du verger bio transfrontalier – Pommes et poires, une approche globale. Ed. Interreg IV TransBioFruit, 84 p.

Kellerhals M., Szalatnay M., Hunziker K., Duffy B., Nybom H., Ahmadi-Afzadi M., Höfer M., Richter K., Lateur M., 2012. European pome fruit genetic resources evaluated for disease resistance. Trees 26:179-189.

Lordan J., Alegre S., Blanco R., Sarasua M.-J., Alins G., 2014a. Aggregation behavior in the European earwig: Response to impregnated shelters. Crop Protection 65:71-76.

Lordan J., Alegre S., Alins G., Sarasua M.-J., Morton A., Garcia del Pino F., 2014b. Compatibility between *Forficula auricularia* and entomopathogenic nematodes to be used in pome fruit pest management. Journal of Applied Entomology 138(9):635-643.

Lordan J., Alegre S., Gatius F., Sarasua M.-J., Alins G., 2015a. Woolly apple aphid *Eriosoma lanigerum* Hausmann ecology and its relationship with climatic variables and natural enemies in Mediterranean areas. Bulletin of Entomological Research 105(1):60-69.

Lordan J., Alegre S., Moerkens R., Sarasua M.-J., Alins G., 2015b. Phenology and interspecific association of *Forficula auricularia* and *Forficula pubescens* in apple orchards. Spanish Journal of Agricultural Research 13(1)

Maalouly M., Franck P., Bouvier J.-C., Toubon J.-F., Lavigne C., 2013; Codling moth parasitism is affected by semi-natural habitats and agricultural practices at orchard and landscape levels. Agriculture, Ecosystems & Environment 169:33-42.

Maalouly M., Franck P., Lavigne C., 2015. Temporal dynamics of parasitoid assemblages on the codling moth. Biological control 82:31-39.

Miñarro M., Dapena E., 2003. Effects of groundcover management on ground beetles (Coleoptera: Carabidae) in an apple orchard. Applied Soil Ecology 23:111-117. DOI: 10.1016/S0929-1393(03)00025-8

Miñarro M., Hemptinne J-L., Dapena E., 2005. Colonization of apple orchards by predators of *Dysaphis plantaginea*: sequential arrival, response to prey abundance and consequences for biological control. Biocontrol 50 (3): 403-414. DOI: 10.1007/s10526-004-5527-1

Miñarro M., Dapena E., 2007. Resistance of apple cultivars to *Dysaphis plantaginea* (Hemiptera: Aphididae): role of tree phenology in infestation avoidance. Environmental Entomology 36(5):1206-1211. DOI: 10.1603/0046-225X(2007)36[1206:ROACTD]2.0.CO;2

Miñarro M., Dapena E., 2008. Tolerance of some scab-resistant apple cultivars to the rosy apple aphid, *Dysaphis plantaginea*. Crop Protection 27:391-395. DOI:10.1016/j.cropro.2007.07.003

Miñarro M., Espadaler X., Melero V.X., Suárez-Álvarez V., 2009. Organic versus conventional management in an apple orchard: effects of fertilization and tree-row management on ground-dwelling predaceous arthropods. Agricultural and Forest Entomology 11:133-142. DOI: 10.1111/j.1461-9563.2008.00403.x

Miñarro M., Fernández-Mata G., Medina P., 2010a. Role of ants in structuring the aphid community on apple. Ecological Entomology 35:206-215. DOI: 10.1111/j.1365-2311.2010.01173.x

Miñarro M., Dapena E., 2010b. Multitrophic effects of organic fertilization and tree-row management in cider-apple orchards. Proceedings of the 14th International Conference on Organic Fruit-Growing, 22-24February 2010, University of Hohenheim (GER), pp. 285-291.

Miñarro M., 2012. Weed communities in apple orchards under organic and conventional fertilization and tree-row management. Crop Protection 39:89-96. DOI:10.1016/j.cropro.2012.04.002

Miñarro M., Prida E., 2013. Hedgerows surrounding organic apple orchards in north-west Spain: potential to conserve beneficial insects. Agricultural and Forest Entomology 15:382-390. DOI: 10.1111/afe.12025.

Nicolas A., Dagbert T., Le Goff G., Hance T., 2015. La lutte biologique contre le puceron cendré du pommier par des lâchers d'auxiliaires en verger. Earth and Life Institute, Louvain-la-Neuve, 30 p.

Parisi L., Gros C., Combe F., Parveaud C.E., Gomez C., Brun L., 2013. Impact of a cultivar mixture on scab, powdery mildew and rosy aphid in an organic apple orchard. Crop Protection 43:207-212.

Parisi L., Jamar L., Lateur M., Laurens F., Lauri P.E., 2014. Adapting apple ideotypes to low-input fruit production agro-ecosystems. In: Bellon S., Penvern S. (eds.), Organic Farming, Prototype for Sustainable Agricultures. Springer, Doordrecht, pp. 131-148.

Parveaud C.E., Brenner J., Libourel G., Albert L., Guérin A., Mercier V., 2014. Verger Bas Intrants : La biodiversité fonctionnelle pour réduire les intrants phytosanitaires. Réussir Fruits & Légumes suppl. 342:12.

Porcel M., Sjöberg P., Swiergiel W.,Dinwiddie R., Rämertand B., Tasin M., 2015. Mating disruption of *Spilonota ocellana* and other apple orchard tortricids using a multispecies reservoir dispenser. Pest Manag Sci 71:562–570.

Rosa-García R., Miñarro M., 2014. Role of floral resources in the conservation of pollinators in cider apple orchards. Agriculture, Ecosystems and Environment 183:118-126. DOI: 10.1016/j.agee.2013.10.017.

Sigsgaard L., Esbjerg P., Philipsen H., 2006. Experimental releases of *Anthocoris nemoralis* F. and *A. nemorum* (L.) (Heteroptera: Anthocoridae) against the pear psyllid *Cacopsylla pyri* L. (Homoptera: Psyllidae) in pear. Biol. Control. 39:87-95.

Sigsgaard L., 2010. Habitat and prey preferences of the two predatory bugs *Anthocoris nemorum* (L.) and *A. nemoralis* (Fabricius) (Anthocoridae: Hemiptera-Heteroptera). Biological Control 53:46-54. http://www.sciencedirect.com/science/article/pii/S1049964409002953

Sigsgaard L., Betzer C., Naulin C., Eilenberg J., Enkegaard A., Kristensen K., 2013. The effect of floral resources on parasitoid and host longevity: Prospects for conservation biological control in strawberries. Journal of Insect Science 13:104. Link: http://www.insectscience.org/13.104

Simon S, Bouvier J.-C., Debras J.F., Sauphanor B., 2010. Biodiversity and pest management in orchard systems. A review. Agronomy for Sustainable Development 30:139–152.

Simon S., Morel K., Durand E., Brevalle G., Girard T., Lauri P.-É., 2012. Aphids at crossroads: when branch architecture alters aphid infestation patterns in the apple tree. Trees Structure and Function 26: 273-282. DOI 10.1007/s00468-011-0629-8

Simon S., Lesueur-Jannoyer M., Plénet D., Lauri P.-É., Le Bellec F., 2016. Methodology to design agroecological orchards: Learnings from on-station and on-farm experiences. European Journal of Agronomy (in press). http://dx.doi.org/10.1016/j.eja.2016.09.004.

Sjöberg P., Swiergiel W., Neupane D., Lennartsson E., Thierfelder T., Tasin M., Rämert B., 2015. Evaluation of temperature sum models and timing of *Quassia amara* (Simaroubaceae) wood-chip extract to control apple sawfly (*Hoplocampa testudinea* Klug) in Sweden. J Pest Sci 88: 301-310.

Stilmant D., Van Bellinghen C., Hance T., Boivin G., 2008. Host specialization in habitat specialists and generalists. Oecologia, 156(4):905-912.

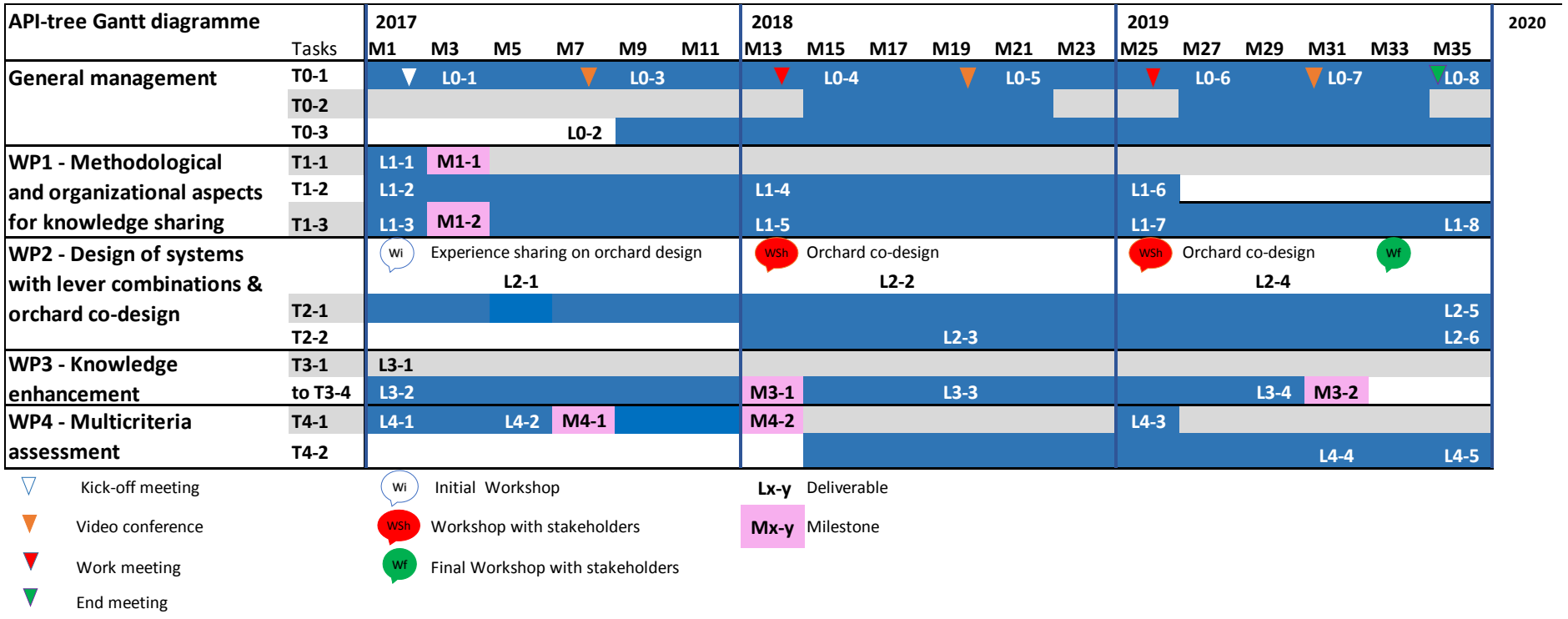
Veres A., Petit S., Conord C., Lavigne C., 2013. Does landscape composition affect pest abundance and their control by natural enemies? A review. Agriculture, Ecosystems & Environment 166:110-117.

Wateau K., Tournant L., Jamar L., 2009. Décoction de *Quassia amara* et lutte contre l'hoplocampe du pommier (*Hoplocampa testudinea* Klug). Actes des Journées Techniques Nationales Fruits et Légumes Biologiques, ITAB-GRAB, Paris, 8 & 9 décembre 2009, pp. 25-30.

Wateau K., Tournant L., Jamar L., Oste S., 2011. Les ravageurs secondaires en verger de production biologique : recherche de nouvelles techniques de lutte contre *Hoplocampa testudinea* Klug et *Anthonomus pomorum* Linnaeus. AFPP - 4ème Conférence Internationale sur les Méthodes Alternatives en Protection des Cultures, 8-10 mars 2011, Lille, France, pp. 535-545.

Zboralski A., Vilarelle M., Colombel E., Tabone E., Vercken E., 2016. Density-dependent dispersal in biological control agents: a reflexion on the side-effects of mass-rearing conditions. Biocontrol. 31(1):13-22. Doi: 10.1007/s10526-015-9696-x

Appendix 4. Gantt chart, project deliverables and milestones



Work packages	Tasks	Activities	Deliverables Lx-y / Milestones Mx-y
General management*	T0-1	Meetings, reporting	L0-1, L0-3, L0-4, L0-5, L0-6, L0-7 Meeting reports L0-8 Final report
	T0-2	Co-training	
	T0-3	Webpages	L0-2 Webpages available
WP1 - Methodological and organizational aspects for knowledge sharing	T1-1	Common framework	L1-1 Common framework finalized
			M1-1 Common framework available
	T1-2	Sharing specific protocols	L1-2 Grid to analyse specific protocols
			L1-4 Shared & harmonized specific protocols
			L1-6 Feedback on specific protocols
	T1-3	Common experiments	L1-3 Common experiments: protocols
			M1-2 Common protocols available
			L1-5, L1-7 Feedbacks on common experiments
			L1-8 Protocols available on-line (records)
WP2 - Design of systems with lever combinations & orchard co-design	T2-1, T2-2	Workshops	L2-1, L2-2, L2-4 Workshop reports
	T2-1	Orchard design	L2-5 Guideline for orchard design
	T2-2	Co-design	L2-3 Report on co-design process
			L2-6 Publication on orchard (co)design submitted
WP3 - Knowledge enchancement	T3-1 to T3-4	Specific experiments on studied levers & common experiments	L3-1 Detailed list of skills & experimental facilities of partners
			L3-2 Report on lacks of knowledge on studied processes
			M3-1, M3-2 (Parts of) studies on processes completed and feedbacks to WP2
			L3-3, L3-4 Publications or congress communications by partners on specific experiments
WP4 - Multicriteria assessment	T4-1	DEXiFruits adaptation to European contexts	L4-1 Demo on DEXiFruits tool (files)
			L4-2 Report on context specificities for tool adaptation
			M4-1 Context specificities identified
			M4-2 DEXiFruits adapted to each European context
			L4-3 Feedback on advantages/ limits of the tool
	T4-2	DEXiFruits use on experimented orchards	L4-4 Report on common results analysis
			L4-5 Final analysis & report