Funded by the European Union

PURE

Pesticide Use-and-risk Reduction in European farming systems with Integrated Pest Management

Grant agreement number: FP7-265865

Collaborative Project
SEVENTH FRAMEWORK PROGRAMME

D7.2
Ex-post assessment of the selected scenarios after testing in real farming conditions

Due date of deliverable: M 48
Actual submission date: M 48
Start date of the project: March 1st, 2011 **Duration**: 48 months
Workpackage concerned: WP 7
Concerned workpackage leader: Christine Poncet
Organisation name of lead contractor: INRA

Project co-funded by the European Commission within the Seventh Framework Programme (2007 - 2013)	
Dissemination Level	
PU Public	**PU**
PP Restricted to other programme participants (including the Commission Services)	
RE Restricted to a group specified by the consortium (including the Commission Services)	
CO Confidential, only for members of the consortium (including the Commission Services)	

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1. Summary

The overall objective of the PURE project is to provide practical IPM solutions to reduce dependence on pesticides in selected major farming systems in Europe, thereby contributing to a reduction of the risks to human health and the environment and facilitating the implementation of the pesticides package legislation while ensuring continued food production of sufficient quality.
Within the PURE project, the objective of WP7 was to design more robust IPM solutions to implement for tomato cultivation, not only in high-tech greenhouse systems (North Europe) but also in low-tech farming systems (South Europe). This can be achieved by designing IPM solutions adapted for different levels of greenhouse technology (based on a combination of strategic options and tactic components) that reduce reliance on pesticides and risks to human health while providing cost-effective investment.
On-farm trials have been performed in Italy, France and Spain. Different IPM solutions have been envisaged, both in terms of pests and pathogens control. A cost-benefit analysis has been performed in order to show the economic impact of IPM methodologies chosen.

2. Objectives

The deliverable D7.2 deals with the ex-post assessment of the selected scenarios after testing in real farming conditions. Herein, the deliverable ex-post assesses and compares, on a multi-criteria basis, the IPM solutions chosen and kept after their real-life test, first on-station and then on-farm, so that performant and viable solutions can be disseminated.
The main outcome in this deliverable is a cost-benefit assessment of the IPM solutions tested and considered as viable. The IPM solutions in this case of protected horticulture have been country specific, with IPM solutions based on the use of generalist predators (mirid species) that work very well in the Mediterranean conditions of Spain; or the combination of other mirid species in

combination with parasitoids (South of France). Also, where soil borne pathogens occurred (south of Italy) the use of micro biological control agents like *Trichoderma spp*. has been tested.

3. Deliverable procedure

A cost benefit analysis of the on-farm experiments has been carried out. First, the cost of biological control (predators and labour) is compared with the costs of chemical treatments (chemicals, equipment and labour). Second, the question of possible increased revenues was raised. Less sprayings can increase physical production (kg/m^2), and increasing revenues is more important than reducing costs. Revenues (€/m2) means tomato production (kg/m2) multiplied by tomato prices (€/kg).
The economic assessment takes into account prior surveys: of the actual market requirements and conditions; and of the farming and agro-food industry performed in the regional systems considered.

Greenhouse tomatoes in Europe

Growing tomatoes in greenhouses shows big differences within Europe. The differences depend to a large extent on growing period or crop cycle. Crop cycles correlate to a large extent with the climate conditions outside and the pricing of tomatoes during the year.
To reduce pesticides residues on the products growers need to use IPM / biological control. Crop protection and the use of IPM / biological control have also a relation with the outside climate conditions and the pricing of tomatoes.
Regarding climate conditions, we defined northern growing areas and southern growing areas. The north includes mainly The Netherlands, Belgium, northwest of France and Poland. The south includes mainly Spain and Italy. The south of France is in between.
In summer the outside temperature is very high in the south. In the south there is also more sunlight during the year. Because of high temperatures in summer, greenhouses are not used during a part of the summer period. So in the south the extra light cannot be used for tomato crops.
Tomato prices are higher in winter and lower in summer. In spring there is a decrease of the price and in autumn there is an increase of the price.

Crop cycles and greenhouse technology

In the north there are mainly long crop cycles and in the south short and long crop cycles. But in the south the long crop cycle is shorter than in the north.
In the north the crop cycle starts in general in November/December and ends in November (The Netherlands and Belgium) or starts in January/December and ends in November (northwest of France).
In the south the long crop cycle starts in general in August and ends in March/April. This long cycle occurs mainly in the south of Spain. Sometimes there are also short crop cycles in Spain. In Italy there are mainly short crop cycles. This is related to the lower temperature in Italy compared with southward Almeria, the biggest tomato area in Spain. In Sicily in the south of Italy there are also long crop cycles but they are not as common as in the south of Spain. The short crop cycle starts in August and ends in December (summer-autumn crop) or starts in January/February and ends in May/June (winter-spring crop). The long crop cycle starts in October/December and ends in June.
In the northern regions high tech glasshouses with heating, screens and climate control by computers are used because of the cold outside temperature and the higher prices of additional production in winter time. In the south plastic greenhouses without much technology are used. Low tech greenhouses are used because of decrease of tomato prices in spring. The use of heating and other technology increase physical production a little in wintertime and extend the crop cycle with substantially additional physical production in spring. Growers do not want to spend money for heating and technology in combination with extra production in periods with lower prices.
In the north substrate is used as growing medium. In the south the tomato plants are mostly grown in the soil.
Because of the longer crop cycle and the high tech greenhouses the physical production per square meter per year is much higher in the north than in the south.

Crop protection

To reduce the use of pesticides for crop protection it is important to use IPM / biological control besides resistance of the crop, climate control in greenhouses and a good physiological condition of the crop. A crop has more problems with pests and diseases when in bad physiological condition.
The crop cycle in the south starts at the end of summer. In this period the outside temperature is very high in the south. This entails a high infection pressure from pests from outside the greenhouses. This causes an additional handicap for biological control in the south. The crop cycle in the north starts at the end of autumn / begin of winter. In this period the outside temperature is low in the north. This entails low infection pressure of pests from outside the greenhouses. This causes an easier starting position for biological control in the north.
The use of pesticides in cultivation of tomatoes has traditional been highest in the south of Europe. The use of pesticides is high because of the planting of the crop in summer with high pest infestation from outside the greenhouses and the use of low tech greenhouses with simple climate control and no heating. Moreover, the spread of viruses by insects is a big problem in the south.
Because of the climate conditions and residue requirements of the market the use of IPM / biological control is common practice in The Netherlands, Belgium and in the northwest of France for many years.
During the last years the use of IPM and biological control has also increased in Spanish tomato crops because of requirements of the exports markets, the use of IPM / biological control in other greenhouse crops (especially sweet peppers) and the presence of suppliers of biological control products in the greenhouse centres of Spain (Almeria and Murcia).
Control of pests with IPM / biological control is technically largely possible both in the north and in the south. Predators for the most pests are available. The major challenges in relation IPM / to reduce the use of pesticides in greenhouse tomatoes are the diseases (airborne and soil born) and nematodes. This is mainly a challenge in the south because of the simple climate control (low tech greenhouses without heating) and growing in the soil. Nematodes are especially a problem in Italy. Probably this has a relation with the soil (clay).

Market prices of quality tomatoes

Tomatoes with low pesticides residues can sold in a higher market segment with higher prices. For example retailers in Germany have the strongest restrictions on residues on vegetables and fruit products including tomatoes, both in number and in level of residues. Germany is also an important country for exporting tomatoes because of the size the German market. Furthermore exports of tomatoes to the German market result in higher prices. Germany pays higher prices for importing tomatoes than other countries. In order to supply the Germany market, the tomato production with low residues cannot without IPM / biological control.
However, pesticides residues are not the only quality aspect of the German market. The results of an exploratory survey with interviews of practical experts around quality aspects for tomato cultivation for exports show other quality aspects. The most important quality aspect is taste and flavour. The second quality aspect is the physical appearance (shelf life, type of tomatoes, colour and package). The other quality aspects like pesticide residues stand in third place.
To export tomatoes to the German market tomatoes must comply with all of these quality aspects. Tomato production with low pesticide residues cannot be realized without IPM / biological control.

On farm experiments and common practice crop cycles

On farm experiments with tomatoes were done in specific crop cycles in different countries: France (southern part), Italy, and Spain.

The case study in France

Crop cycle: Spring-summer, planting in March, ended in September 2013

Cultivar: Bonarda Hybrid / Coeur de boeuf / Maestria
IPM strategy chosen: Releases of generalist predator *Macroluphus pygmaeus*; and releases of parasitoids (*Trichogramma achaeae*) whenever needed depending on *T. absoluta* males trapping. The released dose of parasitoids depends on infestation. The strategy can be completed with *Bacillus thuringiensis* (or Bt) treatments. Monitoring of *Tuta absoluta* adults with pheromone traps is a must.
The 3 study sites have similar characteristics, all of them in south east of France.

Cost analysis
The cost of *Trichogramma achaeae* releases was 25 to 45€/100m² depending on the number of interventions. For comparison, this is the cost of 2 *Macroluphus pygmaeus* releases in South of France conditions (Figure 1).

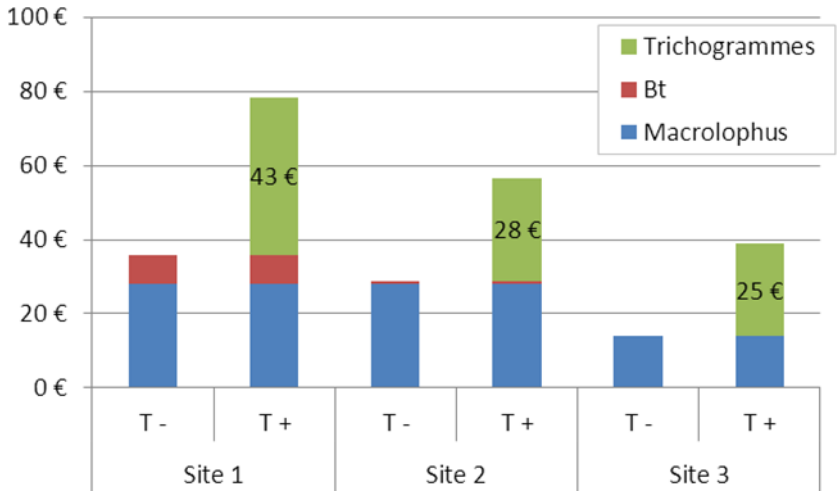

Figure 1: Cost of *Tuta absoluta* control (Euro/100 m2) in three different sites in France (Site 1, Site 2 and Site 3) and two strategies regarding the use or not (T- and T+) of *Trichogramma achaeae*. In green cost of *Trichogramma achaeae* releases, in red cost of *Bacillus thuringiensis* (Bt) treatments, and in blue cost of *Macrolophus pygmaeus* releases.

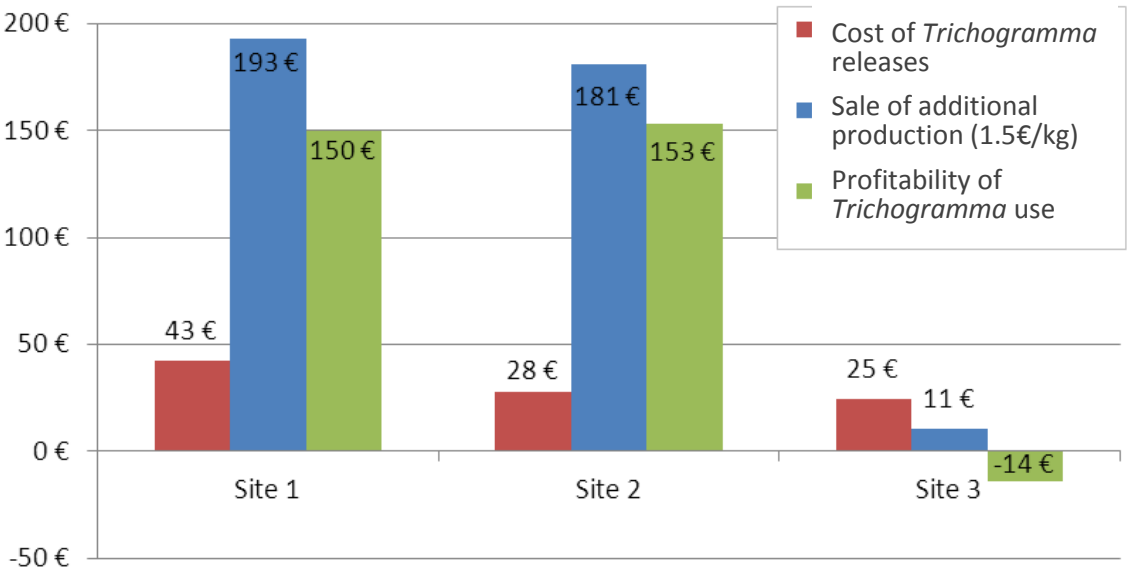

Figure 2: Profitability of *Trichogramma achaeae* use in the biological control of *Tuta absoluta* in three sites in France.

In cases in which pest pressure is high like in this example in site 1 and site 2, the use of *T. achaeae* is economically justified and covered by the additional quality production sales. On the contrary when

pest pressure is low the use of *T achaeae* does not pay back (Figure 2). Consequently, parasitoid releases have to be modulated according to pest pressure and generalist predator installation. Under these conditions, monitoring pest and generalist predator installation is a must.

The case study in Italy

Crop cycle: Spring-summer, planting in April, ended in September 2013
Cultivar: Sir Elyan (green fruit harvesting)
IPM strategy chosen:
1 - Farm Control: chemical-based control (1700 m^2);
2 - False trail + biological control (1000 m^2).

Table 1. Cost-benefit analysis of the false trail+ Biological control strategy against the usual one based on chemical control in Italy.

	Treatment Costs/1000 m2	Non marketable tomatoes /1000m2	loss of revenue (0,5 €/Kg)	loss of revenue (0,9 €/Kg)	Total cost/1000m2 (0,5 €/KG)	Total cost/1000m2 (0,9 €/KG)
Farm control conventional	214	2%	300 Kg (150 €)	300 Kg (270 €)	364 €	484 €
False trail + BC	254	0	0	0	254 €	254 €
Costs increase	+ 40 € (+16%)	0	150 €	270 €		
False Trail *vs* conventional revenue					+ 110 €	+ 230 €

* The false trail vs. conventional revenue represents the difference in revenues obtained with these two strategies. In this case, +110 € and +230 € represent an extra gain or income obtained in the biological control strategy.

Cost analysis
On-farm experiments in Italy (Campania) gave higher cost for IPM (combination of biological control methods) than for no IPM (only chemical crop protection). However, in the situation with IPM there was an increase of physical production (kg/m^2). This was related to the improvement of the physiological condition of the crop. Thus, similar to the French case, the extra gains or additional revenues (represented in Table 1 by +110 € and +230 €) largely compensated the cost increase of the biological control strategy (Table 1).

The case study in Spain

Crop cycle: autumn-spring; planting in September 2012; ended in May 2013
Cultivar: Raf tomato
IPM strategy: Biological control strategy based on the release of *Nesidiocoris tenuis* in the nursery (0.5 ind./plant) with the supply of *Ephestia kuehniella* eggs as alternative food. When needed treatments with *Bacillus thuringiensis* (3 Bt treatments in average). This strategy was tested on 4 greenhouses of 0.3, 0.5, 0.6 and 1 ha. No pesticides were used in any of the 4 tested greenhouses.

The biological control strategy was compared to the chemical strategy previously used (season 2011-2012 and before). The chemical pesticides strategy used between 12 and 15 sprayings/season.
Results:

- Yield: in the four greenhouses, the yield was approximately 9 kg/m^2 in both crop seasons.
- Fruits bored by *Tuta absoluta*: BC strategy < 0.1 %; chemical strategy: 10 %
- Fruits damaged by thrips or whiteflies: minimum incidence of thrips and no incidence of whiteflies.

Cost analysis
The cost of the biological control strategy based on the release of the predator *Nesidiocoris tenuis* was lower. The BC strategy required the addition of supplementary food or alternative prey for the mirid (*Ephestia kuehniella* eggs) and also treatments with Bt, until mirids reached population levels that control the pests.

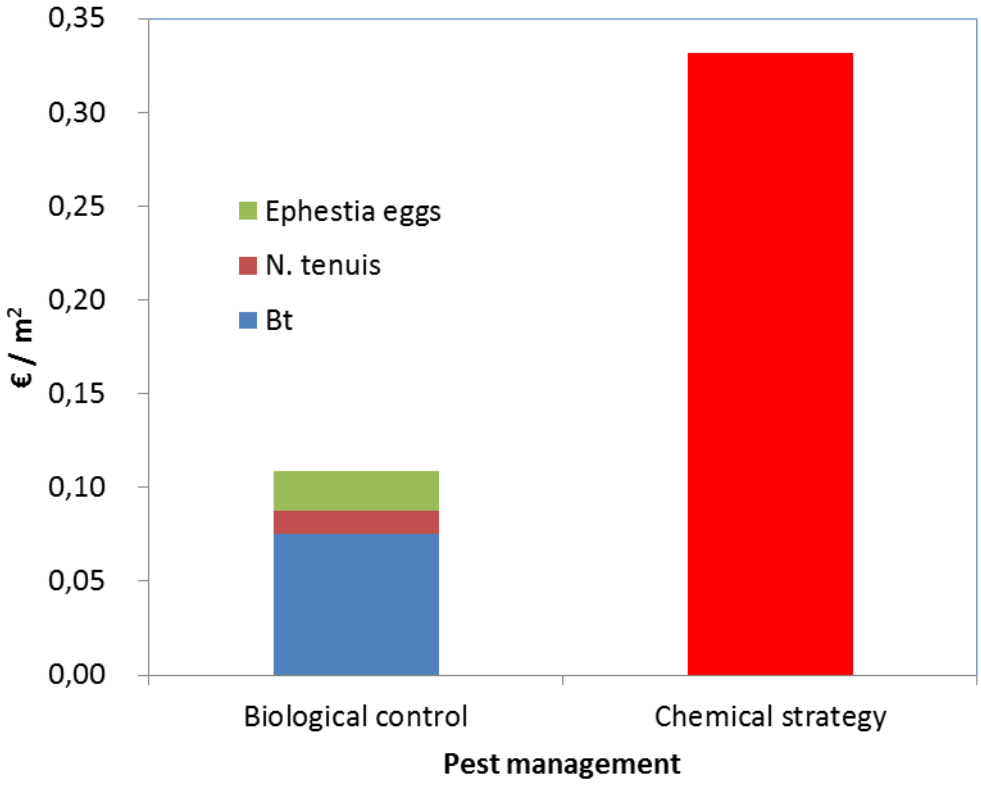

Figure 3. Cost of the pest management strategies: biological control vs. chemical strategy

Moreover, the benefit of the biological control strategy was much higher than the chemical strategy, since the marketable yield of tomatoes was also higher (0.1% vs. 10% of infested tomatoes by *Tuta absoluta* under biological control and chemical control strategies respectively).

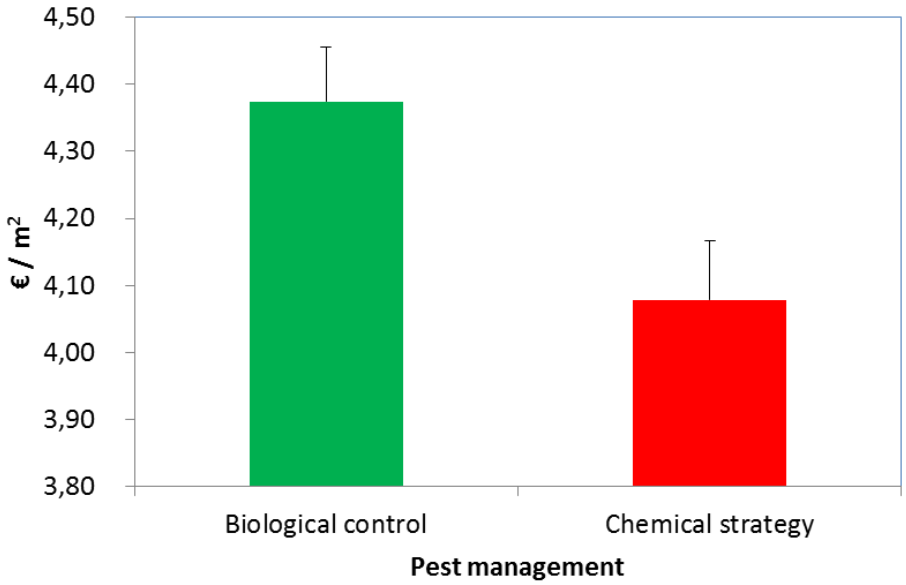

Figure 4. Benefit (€/m²) based on marketable tomato yield. Average data from 4 greenhouses.

Unlike the French and Italian cases, in the Spanish case the biological control strategy is cheaper than the chemical control strategy. Moreover, the biological control strategy based on the release of the generalist predator *Nesiodiocoris tenuis* worked alone (only very few sprayings of *Bt*) and did not need the use of any other BCA like for the French (*Trichogramma achaeae* releases) or the Italian (pheromone traps) strategies.

4. Conclusion

The general conclusion we draw up from these on-farm experiments and cost benefit analyses is that the IPM strategy based on biological control seemed more expensive but it finally pays for. Two main reasons can be highlighted: first, in the experiments presented there have always been more yield, so more produce to sell; and second, the IPM strategy based on biological control allows the access to exports and markets that pay better.
In the Spanish case, besides the main reasons already stated, the biological control strategy was cheaper than the chemical one, so it resulted twice profitable.

5. Annex I

List of relevant publications

Velden, N. van der, R. Suay, A. Urbaneja, M. Giorgini, M. Ruocco, C. Poncet en A. Lefèvre, Recent developments and market opportunities for IPM in greenhouse tomatoes in southern Europe. LEI Memorandum 12-077, LEI Wageningen UR, The Hague, 2012.
Velden, Nico van der, Challenges on IPM implementation; Market demand and product prices Round table discussion: How could research and developpment contribute to the implementation of IPM, IPM Innovation in Europe, Poznań, January 14th 2015.