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

D1.5
Cost-benefit analysis of IPM solutions

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 1

Concerned workpackage leader: Jean-Noël Aubertot

Organisation name of lead contractor: JRC-IPTS

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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European Commission, Joint Research Centre (JRC),
Institute for Prospective Technological Studies (IPTS), Agrilife Unit, Edificio Expo.
c/ Inca Garcilaso, 3, 41092 Seville, Spain
Authors: Marianne Lefebvre, Stephen Langrell, Sergio Gomez-y-Paloma

Abstract

The most comprehensive summary of private, producer-level economic evaluations of IPM programs to date was developed by Fernandez-Cornejo et al. (1998), updating the prior work of Norton and Mullen (1994). The 51 studies summarised highlight the fact that while most IPM programs increased profits, increased yields, and reduced pesticide use, these effects did not occur universally. The PURE project aimed at completing this evidence in six key European farming systems (winter-wheat based rotations, maize-based cropping systems, field vegetable crops, pomefruit, grapevine, protected vegetables) and a range of IPM solutions from intermediate (solutions easy to implement and scientifically validated) to advanced (solutions in the experimental stage). Collecting data on costs and benefits of IPM solutions and computing meaningful indicators is a first step to understand the drivers and incentives necessary for widespread IPM adoption. The cost-benefit analysis (CBA) methodology developed in task 1.4 enables to aggregate all the information on monetary costs and benefits collected in the on-farm and on-station trials.

Keywords: Economic evaluation, Cost Benefit Analysis, Intregrated Pest Management, Adoption, Experiment, Incentives

List of abbreviations

CAP: Common Agricultural Policy

CBA: Cost Benefit Analysis

EPPO: European and Mediterranean Plant Protection Organization

IPM: Integrated Pest Management

Countries

DE: Germany

DK: Denmark

ES: Spain

FR: France

HU: Hungary

IT: Italy

NL: Netherlands

PL: Poland

SL: Slovenia

UK: United Kingdom

Objectives

According to the DoW, the objectives of the task were the following.

Task 1.4 will develop an appropriate economic methodology that will serve as a critical component in the design-assessment-adjustment cycle approach for identifying viable IPM solutions, and to provide a final set of comparative assessments of candidate IPM solutions from Pillar 1 (WPs 2–7).

The methodology will use as input (i) empirical data from identified indicators derived from field level assessments (particularly as elaborated with DEXiPM in Task 1.2), with the inclusion of other indicators where necessary, (ii) economic information on input costs and output prices, together with their annual and possibly seasonal variability. As well as farm-level economic feasibility per se, the methodology will also allow an economic comparison of proposed IPM solutions with alternative conventional chemical approach(es) and/or or other management scenarios, based on a suite of defined empirical indicators. Various components of risk (yield risk, price risk) will be included in the comparative analysis.

With respect to the design-assessment-adjustment cycle approach, a maximum of 3 iterations, representing a maximum of 3 growing seasons within the 4 year lifespan of the project, are foreseen. The repeating cycle of the analysis will rely on the timely and accurate provision of empirical data from each leader of WP2-7.

Given the multiplicity of crops, farming systems and iterations involved in the assessment cycle, a final aim of this task will be to examine the possibility of performing a meta-analysis based on all the data generated, in order to explore whether thresholds and constraints can be identified that would serve to delimit the multidimensional space within which IPM solutions are profitable. With such an extension of the methodology, cautious extrapolation of the results to other crops/farming systems/pest risks not explicitly covered may be possible. Consideration of the wider socio-economic impacts, at farm level and at a more aggregated (small) regional level, might also be included in the analysis on a site-specific basis.

This analytical framework can be extended to cover clusters of farms where appropriate, and can provide insights into whether collective action on IPM (whether by clubs or consortia of farmers, or under the aegis of local administrations) would provide enhanced benefits in terms of controlling pest incidence and improving financial feasibility for participating farms.

Table 1 presents the outcomes delivered as compared to outcomes stated in the Dow with the necessary explanations.

Table 1: Outcomes delivered as compared to outcomes stated in the Dow

Outcomes as stated in the Dow	Outcomes delivered
1. Definition of quantitative indicators (at various levels – farm, landscape) and appropriate interrogative database/archive.	Before defining the relevant quantitative indicators, the scope of the cost benefit analysis to be conducted in PURE had to be defined. In the textbooks, CBA generally includes evaluation of the costs and benefits at society level, i.e. beyond farm gates. The difference between the farm and society's viewpoint occurs because the costs of IPM are not fully borne by the farmer (e.g. costs of training born by the institutions in charge of IPM project) and benefits can be visible for societal groups other than the farmer (e.g. positive impact on water quality and biodiversity due to reduction in pesticide use, reduction of resistance, reduction of health risk for consumers…). But it was decided that there will be no evaluation of such costs and benefits, and that task 1.4 in PURE would focus only on the financial evaluation of cost and benefits with a market value at farm level. With this framework in mind, the private CBA methodology was adapted to evaluate IPM solutions. The methodology was discussed in several occasions with economists from other WP (Wim Van Dijk (WP3) and Jan Burma (WP5)). A meeting was organised in Seville on the 15th and 16th of May 2012 to discuss this methodology.
2. A database of most relevant market price data, specific to each commodity, under study for IPM development.	Given the high variability in prices obtained by the farmers across regions, variety …, it was decided not to rely on national market prices. Rather, experimenters or farmers from WP2-7 have indicated the price they got for the crop produced, or the price usually paid in the region if their output is not sold. Moreover, we investigated whether farmers currently get higher price crops produced under IPM. For all the crops (wheat, maize, grapes, pomefruit) and regions covered by the PURE project, the answer is no. In some cases, farmers may have access to specific markets with IPM, but do not get higher price. The impact of output price on the profitability of IPM is analysed through sensitivity analysis (see section 7.6).
3. Definition of an integrative platform for the quantitative economic comparative analysis of candidate IPM solutions with conventional management scenarios for application.	An excel template was designed to gather all relevant data for the cost-benefit analysis. In technical experiments material inputs, physical yields and quality classes are usually recorded quite precisely. But input and output prices and labour often get less attention and are rarely recorded. Consequently, providing precise instructions to the technical researchers for the collection of economic data was an important attention-point in the procedure. A first generic template was circulated, together with instructions on the 22nd of June 2012. Then, the template

	had been made WP-specific in order to facilitate data collection by the technical researchers. For example for WP2, data needs to be collected for each crop of the rotation. The template was therefore adapted for system experiments (delivered 21/01/2014). For WP6, the template was also adapted for partial analysis and to allow different values for grape prices and contractor charges at regional level (delivered 27/08/2013). Annex A consists in the instructions provided to the technical researchers to fill-in the template.
4. Annual ex-post economic comparative assessment, as part of the iterative development cycle, for each candidate IPM system under development, in support of WP1 Task 1.2 and WPs 2 – 7.	During the project, we have realised that WPs were highly heterogeneous in terms of human resources available to perform the economic evaluation. While WP3, 4, 5 and 7 could perform the calculations internally (using the methodology proposed), support from JRC-IPTS was requested by WP2 and 6. Given the time necessary to set-up the methodology for economic analysis and the important amount of work technical researchers already had to perform for other dimensions of the project, economic data collection had not been realised on an annual basis. No data were provided to IPTS before end of 2013, therefore no annual assessment was performed. Economic results were computed for 2012, 2013 and 2014 at the end of the project. For WP3 and 5, economic evaluation has been conducted annually, as part of the iterative development cycle.
5. Final report on the *ex-post* economic comparative assessment of each candidate IPM system.	D1.5 presents CBA methodology. It was agreed with the partners of the project that the results of the CBA will be included in the deliverables of ex-post assessment of each WP.
6. Potentially, a meta-analysis based on all the data generated, in order to explore whether thresholds and constraints can be identified to delimit the multidimensional space within which IPM solutions are profitable.	After discussion with PURE partners, it was decided that DEXiPM will be the tool used for this meta-analysis. The choice of DEXiPM (*ex-post* assessment version) was deemed to be more relevant for meta-analysis given that it involves a multicriteria assessment (see deliverable D1.7).

Moreover, beyond the work planned in the DoW, two complementary tasks were performed.

First, we have conducted desk research on the incentives and policies likely to encourage European farmers to adopt IPM guidelines. The idea is that positive Cost Benefit Analysis is not sufficient to insure widespread adoption. Other factors are at play and should be presented to have a more complete picture of the drivers of IPM adoption. The results of this structured literature review have been published in a peer-review article: Lefebvre, M., Langrell, S. and Gomez-y-Paloma, S. (2014) *Incentives and policies for integrated pest* *management in Europe: a review*, Agronomy for sustainable development, DOI 10.1007/s13593-014-0237-2. We reproduce in annex B the content of this article.

Second, the Cost Benefit Analysis as defined in task 1.4 provides very little guidance on the benefit side. In order to fill this gap, we have conducted an economic experiment with consumers on their preferences for tomatoes produced under IPM guidelines. More precisely, we investigated how IPM products consumption would be influenced by a reduced availability of conventional products, when organic tomatoes are also available. Such information is useful to make effective marketing and pricing decisions of IPM products in the new legislative environment, according to which all farmers should follow IPM guidelines (Sustainable Use of Pesticide Directive). This work has been presented in the XIVth Congress of the European Association of Agricultural Economists: Coralie Biguzi, Emilie Ginon, Sergio Gomez-y-Paloma, Marianne Lefebvre, Stephan Marette, Guillermo Mateu, Angela Sutan, *Consumers' preferences for integrated pest management: the case of tomatoes*, EAAE conference 26-29 August 2014, Ljubljana. We reproduce in annex C the content of this article.

Methodology for the cost benefit analysis

The general idea of the CBA is to compare the economic performance of the reference system and the innovative IPM systems (intermediate and advanced). In order to do so, the experimenters[1] were asked to specify the operations realised in the three stages of production:

- Pre-sowing (operations on cover crops, ploughing or other tillage, seed bed preparation, seed treatment, habitat manipulation, actions to improve biodiversity, sowing…) and sowing
- Husbandry (fertilisation, herbicide, fungicide and insecticide application, mechanical weeding, biological control, irrigation, exclosure netting…)
- Harvest (crop or fruit harvest, products sorting and grading, pest management for conservation…)

For each of the operations, they were asked to specify the type of operation or machinery involved, the labour quantity for those operations requiring no equipment, the quantity and type of inputs as well as their prices. The list of data collected is presented together with the instructions in Annex A. In the following sections, we describe specific aspects of the methodology developed in task 1.4.

1. Partial vs Complete CBA

In order to give maximal flexibility to fit with the constraints of each crop/WP, two possible approaches to cost benefit solutions have been retained in task 1.4: the complete and partial CBA (Table 2).

Table 2: Complete and partial cost benefit analysis – definition and WP concerned

	Description	WP concerned
Complete CBA	Information on costs is collected for all operations. This approach is relevant when the tested IPM solution corresponds to an important change in the system, i.e. impacting various operations.	WP2, WP3
Partial CBA	When the tested IPM solution corresponds only to a marginal change (impacting only 1 or 2 operations for example), data are collected ONLY for these operations impacted by IPM. The economic analysis limits to the comparison of the extra costs or costs saving associated to the IPM solution. Operations that are the same in both the reference system and the IPM system (e.g. fertilisation) are left out of consideration.	WP4, WP5, WP6, WP7

[1] Experimenters refer to the agronomists, plant pathologists, technicians working on the experimental stations … partners of the PURE project.

2. Defining the reference situation

The tested innovative cropping systems were compared to references. The definition of the reference is of great importance to interpret the results of a CBA. Each partner was free to decide the reference experiment. In most cases, the reference plot was cultivated according to standard practices in conventional agriculture, i.e. primarily based on chemical crop protection. Moreover, IPM solutions tested are classified either as "intermediate" or "advanced".

3. Analysis of cropping systems based on crop sequence

For the WP2 and 3, economic comparisons are based on the entire rotation, respectively winter wheat- and maize-based rotations, not just the most profitable crop in each. Annualised gross margin is estimated by averaging net gross margin across the years corresponding to the rotation length (one complete repetition of a crop sequence), and across each of the individual crop of a particular crop rotation.

For some of the experimental stations, all the crops in a given system are grown every year: in a two-crop rotation, half of the system's crop land is planted to each crop; in a three-crop rotation, one-third of the crop land is planted to each crop. This allows for the annualised net gross margin of any particular cropping system to be calculated for each year of the study, as a proxy for the profitability of the rotation, after controlling for the confounding effect of climatic and other natural factors.

For those experiments where not all crops of the rotation are present each year, it is not possible to measure the net impact of IPM because the differences in the annualised net gross margin between cropping system can also be due to the varying climatic conditions across years.

For single crops experiments, gross margin is calculated on an annual basis, but also averaged out over the three years of the project (season 2011-2012, 2012-2013, 2013-2014).

4. Estimation of costs

In order to simplify and harmonise data collection, we have assumed that all operations are conducted by an external operator. Contractors usually charge a price per hectare depending of the type of operation. This price includes the costs of machinery, labour and fuel. Input costs (mineral fertiliser, organic fertiliser, insecticide, fungicide, herbicide, bio-chemical agents, other crop protection input, seed, water) are not included in contractor costs and filled-in apart.

As a result of this assumption, labour costs were calculated apart only for the operations that do not require machinery (eg. scouting). For each of these operations, the time dedicated to monitoring disease/scouting is registered. The labour quantity was multiplied with hourly wages according to Farm Accountancy Data Network at country level (2009) (Table 3). We assume an average value for labour, irrespective if it is family labour or hired labour. Unfortunately, only few technical researchers registered scouting time, impeding any general conclusion on whether IPM is more labour-intensive.

Some countries have publicly available database, where the cost per hectare of different operations are specified (e.g. barème d'entraide in France). In other countries, partners were asked to rely on expert information to provide the values for contractor costs for their national situations. All countries have used the same methodology, i.e. costs including labour, machinery and fuel. When further assumptions were needed to provide such default values, partners were asked to provide the most relevant values for their specific regions or experiments. Examples for the contractor cost default values used for WP2 are presented in Table 4. To avoid errors, the excel template allows automatic filling of the contractor cost, on the basis of the nature of the operation (or machinery type), crop and country concerned, using the default values specified in Table 4.

Fixed costs such as land, buildings (including greenhouse) or insurance are not included.

Table 3: Hourly wage in agriculture (€) FADN 2009

DK	DE	ES	FR	HU	IT	NL	PL	SL	UK
23.43	10.05	7.25	13.02	3.84	8.81	15.44	2.77	3.28	10.79

Note: Hourly wage in agriculture are calculated as follows: SE 021/ SE 370
SE 021: Paid Labour inputs - HOURS: Total paid labour input in hours
SE 370 Wages paid - EURO: Wages and social security charges (and insurance) of wage earners. Amounts received by workers considered as unpaid workers (wages lower than a normal wage) are excluded.

Table 4: Contractor costs (including costs of machine, labour and fuel) for winter-wheat based rotations

DE (€/ha)	MA: maize	WB: winter barley	WW: winter wheat
Ploughing and pressing	135	132	97
Seed bed preparation	45	45	31
Sowing	64	43	37
Spraying	15	15	12
N fertilisation	10	9	8
Mechanical weeding			13
Combining	450	186	155
DK (€/ha)	all crops		
Ploughing and pressing	90		
Harrowing	20		
Rotary cultivation (Dyna Drive)	40		
Sowing	47		
Combi-drill (seed and fertiliser) with power harrow	80		
Rolling	20		
Top dressing fertiliser	18		

Spraying	20
Mechanical weeding (weed harrowing)	17
Mechanical weeding (interrow cultivation)	46
Mechanical weeding (interrow cultivation+band sparying)	60
Combining	133
FR (€/ha)	all crops
Ploughing and pressing	62
Sowing	79
Rolling	11
Top dressing fertiliser	5
Spraying	8.5
Mechanical weeding	11
Combining	97
Maize harvest	70
Crushing	35
Mowing	21
Tedding and raking/swathing	27
Balling	34
Shallow tillage	20
PL (€/ha)	all crops
Ploughing and pressing	83
Harrowing	22
Sowing	53
Removing straw	50
Top dressing fertiliser	20
Spraying	16
Mechanical weeding (weed harrowing)	20
Mechanical weeding (interrow cultivation)	38
Mechanical weeding (interrow cultivation+band spraying)	52
Combining	78
UK (£/ha)	all crops
Ploughing and pressing	64.25
Combi-drill (seed and fertiliser) with power harrow	59.3
Rolling	12.4
Top dressing fertiliser	9.88
Spraying	9.76
Combining	103.78
Baling (calculated at 3.5 Hesston bales per acre @£6.50 per bale and doing 50 bales/hr)	56.22

5. Benefits

Beyond the impact of IPM on yields, the CBA should account for impact on crop quality. Therefore, output is described by category (low, medium and high quality). The criteria used to classify the products between high, medium and low quality can be fruit category, residue level, micotoxin level, sugar and acidity level (grapes), animal versus human feed (maize) … Given than most experiments were conducted on-station, differentiation of output was not always possible and most of the output was qualified as medium quality. Nevertheless, the methodology developed account for this possibility.

In each output category, the yield corresponds to the part of the harvest that can be sold in the marketplace (or used for self-consumption). Output price is the farm gate price. When the harvested crop are sold to different market segments (local, exports, cooperatives…), the price is calculated as the weighted average of prices in the different markets, where the weight corresponds to the share of each market in total sales. If the output is not sold (on-station experiments), the price usually paid in the region was used. Moreover, we investigated whether farmers currently get higher price crops produced under IPM. For all the crops (wheat, maize, grapes, pomefruit) and regions covered by the PURE project, the answer is no. In some cases, farmers may have access to specific markets with IPM, but do not get higher price. The same price is therefore used for conventional and IPM crops. The impact of output price on the profitability of IPM is analysed through sensitivity analysis (see section 7.6).

The potential impact of government support payments on cropping system choices was considered, but we chose not to use them for the analysis, as one of the goals of this research was to investigate cropping systems that do not rely on subsidies to be profitable. Moreover, given that the direct payments per hectare are independent from farming practices, they will not impact the comparison of the economic performance of IPM with the reference. Moreover, with the translation of the Sustainable Use of pesticide Directive in the Good Agricultural and Environmental practices of the Common Agricultural Policy, land under IPM cannot be further supported under Agri-Environmental schemes. Indeed, agri-environment-climate payments can cover only those commitments going beyond mandatory standards. Therefore, Member States will not be permitted to support compliance with IPM general principles after 2014. This further justifies not including agri-environmental subsidies in the evaluation of the economic performance.

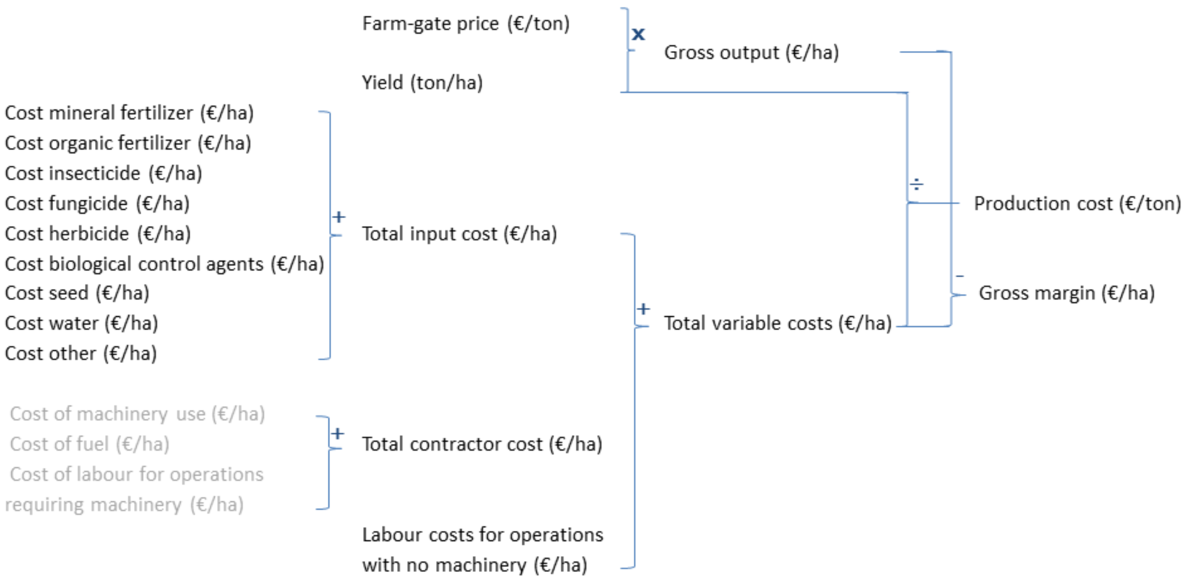
6. Integrated indicators CBA

The indicators chosen should be meaningful for the decision maker (in this case the farmer) in order to determine whether IPM is worthwhile. We have chosen two main indicators:

- The gross margin is obtained by calculating the gross output (by multiplying the production by the farm-gate price received for the product), and deducting the variable costs of the production. Gross margin analysis is also called partial budgeting, as only variable costs are included and fixed costs are excluded.
- The production cost (the sum of the variables costs) expressed by ton of output.

The calculation of these two indicators is described in Figure 1.

Figure 1: Selected indicators of economic performance



Note: The detailed costs in light grey are not available. In most countries, *ex-post* assessment leaders could get access to default value for total contractor costs (including labour, fuel and machinery costs) from national sources, with no breakdown of cost for each category of expenditure.

7. Risk assessment and sensitivity analysis

A risk assessment consists of studying the probability that the IPM farming practices will achieve different performance level[2]. Indeed, it is likely that the results of the economic evaluation are correct on average, but not really informative for a farmer that will implement IPM in slightly different conditions. For example, the data regarding contractor costs suggested may be valid only approximately. One may also have doubts about the generality of the results when data have been collected during three years with considerable climatic variations in the three years. Lastly, most solutions have been tested on-station, and it may cast doubts on the validity of the results in a real farm context.

The first step for risk assessment consists in running sensitivity analysis. Sensitivity analysis allows the determination of the 'critical' variables or parameters of the model. Such variables are those whose variations, positive or negative, have the greatest impact on the economic performance. The analysis is carried out by varying output prices and determining the effect of that change on the gross margin. We have calculated the gross margin for different "output price factors" (0.5, 0.75, 1, 1.25, 1.5), where a factor equals to 0.5 corresponds to the prices of all crops be equal to half of the current prices. This allows comparing IPM systems with the reference for different price conditions. If the IPM system

[2] Traditionally, a distinction between risk and uncertainty concepts is made. In some circumstances there is just uncertainty, but in other cases this can be transformed into 'risk' with an assessment of probability distributions indicating the likelihood of the realised value of a variable falling within stated limits (EC 2008).

is more profitable than the reference system only for very specific output prices, then it suggests the solution is rather risky.

Conclusion

Task 1.4 has allowed developing a sound methodology for the evaluation of the financial performances of a range of IPM solutions from intermediate (solutions easy to implement and scientifically validated) to advanced (solutions in the experimental stage). The main challenge consisted in developing a methodology: i) flexible enough to account for the differences across cropping systems (e.g. perennial vs arable crops, unique crop vs crop-rotation, change in one parameter vs system experiment); ii) simple enough for data collection to be handle by technicians and experimenters also involved in many other time-consuming tasks (including management of the experiments, environmental evaluation…). The cost-benefit analysis (CBA) methodology developed in task 1.4 enables to aggregate all the information on monetary costs and benefits collected in the on-farm and on-station trials of the PURE project. Results allow understanding to what extent other non-economic incentives are necessary for widespread IPM adoption.

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Annex A: Instructions to fill-in the Cost Benefit Analysis Excel template

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

Data collection for Cost Benefit Analysis (Task 1.4)

INSTRUCTIONS TO FILL-IN THE TEMPLATE

We hope the instructions cover all the possible questions you may have. If the instructions and examples provided are not sufficiently clear and if you have questions concerning how to fill-in this template, do not hesitate to contact Marianne.Lefebvre@ec.europa.eu. We will all benefit from high data quality.

WHAT? The objective of this template is to collect economic data for the Cost Benefit Analysis (CBA) of IPM solutions -task 1.4-.

Results of the CBA can be used in the deliverables of *ex-post* assessment within each WP. IPTS may also use these data to produce the deliverable "Annual *ex-post* economic comparative assessment of diverse candidate IPM system under development".

In case of any peer-review publication coordinated by IPTS using the economic data collected by one or several WP, credit will given to the person who contributed to the collection of economic data in each WP (authorship)

WHO? The ex-post assessment leader of each WP is responsible for collecting the data and sending **one excel file per country per year** to JRC IPTS (Marianne.Lefebvre@ec.europa.eu).

HOW? One excel file corresponds to one country. Each sheet corresponds to one crop of the rotation on one experimental site and includes the different strategies tested (Reference, IPM intermediate, IPM advanced) in 3 columns.
In order to add new crops and/or new sites, simply copy paste the sheet CROPi_SITEi and rename each sheet (eg: Crop2_Grignon). Duplicate the sheet CROP1_SITEi_2012 as many times you need in order to include the different crops grown.

WHEN? One excel file with the information of all trials will be sent each year.
There are two possible approaches:

- Complete: In order to perform a full Cost Benefit Analysis, information on costs will be collected for ALL operations. This approach is relevant when the tested IPM solution corresponds to an important change in the system, i.e. impacting various operations.

- Partial: When the tested IPM solution corresponds only to a marginal change (impacting only 1 or 2 operations for example), a partial budget approach can be used, i.e. data will only be collected ONLY for these operations and the economic analysis will be limited to compare the extra costs or costs saving associated to the IPM solution.

The ex-post assessment leader of each WP is responsible for determining which approach is relevant, according to the number of operations impacted by the IPM solution. Please contact IPTS for any doubt on this issue.

Rk1: You can **include more operations** (10 by default) by copy/pasting the 25 lines corresponding to each operation

Rk2: Indicate the quantities of labour, machinery and inputs as necessary to conduct the operation on the plot **per ha**. Quantities and costs for the plot will then be calculated taking into account the surface (exp_surface and operation_area, where operation_area can be lower than 100% if not all the plot is concerned by the operation).

Rk3: Please **do not modify the names of the variables or operations** (so that we can use the same computation code for all WP).

Rk4: The formula are functioning for a maximum of 1000 lines. **Please do not fill-in after line 1000.**

Rk5: Do not hesitate to use the "comments" line !

GENERAL DATA		
exp_WP	*number*	Number of the working package in PURE
exp_year	*yyyy*	year of the harvest
exp_country	*list*	Country of the experiment
exp_site	*text*	site or region
exp_plot	*list*	"Reference" corresponds to the conventional strategy. "Intermediate" corresponds to the IPM solutions easy to implement and scientifically validated, whereas "Advanced" corresponds to IPM solutions in the experimental stage.
exp_crop	*text*	the crop can be different for the different strategies (eg. winter wheat in the Reference and winter barley in the Intermediate)
exp_solutiondescription	*text*	short description of the IPM solution, including the crop sequence in case of system experiments
exp_farmstation	*list*	specify on-farm / on-station
exp_surface	*ha*	surface of the plot in ha

VARIABLE COSTS		
operation_description	*text*	describe with words the type of operation (specify if different actions are combined in one operation)
operation_category	*list*	specify the category of operation Pre-planting and planting (operations on cover crops, ploughing or other main tillage, seed bed preparation, seed treatment, habitat manipulation, actions to improve biodiversity, sowing…) Husbandry (fertilization, herbicide, fungicide and insecticide application, mechanical weeding, biological control, irrigation, exclosure netting…) Harvest (crop or fruit harvest, products sorting and grading, pest management for conservation…) Rk: In the case of perennials, the costs of planting operations will not be collected. We only consider the costs from the moment where the trees or vines are already in full production. When some post-harvest operations are required in order to prepare the next season, these operations should be included in "planting" of the next-year.
operation_date	*yyyy-mm-dd*	
labour_quantity	*hours*	Estimate the required labour demand for the operation that do not require machinery (eg. scouting), give the hours in one decimal. If the operation requires machinery, indicate "0" in labour_quantity. The contractor_cost wil include contractor charges including labour.
machinery_type		select from the list of operations/machineries (default value contractor costs)
contractor_cost	*€*	computed automatically from the default value sheet.
input_category	*list*	specify if mineral fertilizer, organic fertilizer, insecticide, fungicide, herbicide, bio-chemical agents, other crop protection input, seed, water
input_name	*text*	specify the commercial name of the product if applicable
input_unit	*text*	eg: ton, kg, gramme, litre, number of seeds …
input_quantity	*In unit*	
input_price	*€/unit (taxes incl)*	
input_cost	*€*	Calculated automatically from quantity and price. Nevertheless, you can fill-in directly the cost/ha if you don't know the detail for the quantity/ha and the price/quantity.
input_comment	*text*	explain concerns you have concerning the data or specify the source of the data.
BENEFITS		
output_category	*list*	In most cases, there will be one output category only. In case of differentiated products, indicate high, medium or low quality.

output_description	*text*	Specify the criteria you use to classify the products between high, medium and low quality need to be specified (eg: fruit category, residue level, micotoxin level, sugar and acidity level-wine-, animal versus human feed -maize- ...)
output_yield	*ton*	Yield achieved per ha (part of the harvest that can be sold in the marketplace or used for self-consumption)
output_price	*€/ton*	output farm-gate price (use national prices if the production of the experimental station is not sold)
output_pricecomment	*text*	indicate the reference used for the price
output_revenue	*€*	calculated automatically from quantity and price

Annex B: Incentives and policies for integrated pest management in Europe. A review

Lefebvre, M., Langrell, S. and Gomez-y-Paloma, S. (2014) *Incentives and policies for integrated pest management in Europe: a review*, Agronomy for sustainable development, DOI 10.1007/s13593-014-0237-2.

Abstract: Integrated pest management and organic farming are alternatives for sustainable agriculture and less pesticide use in the European Union. All professional users of pesticides in the European Union should follow the general principles of integrated pest management from 2014. States should report to the European Commission on their national action plan for the effective application of those guidelines. The major remaining issues are: 1) when guidelines are not already applied, what incentives would encourage European farmers to adopt those guidelines? 2) How and to what extent should public money be used to promote the adoption of guidelines? Here we review the adoption of integrated pest management in Europe. We deliver a framework to understand the drivers of changes in farmers' pest management practices. This framework also helps to understand farmer reaction to different policy incentives.

1. Introduction

Health and environmental concerns about the risks posed by the use of pesticides have led the European Union to introduce a series of measures in 2009 commonly referred to as the "pesticides package", consisting in four pieces of legislation related to pesticides use[3]. Within this package, the Sustainable Use of pesticides Directive provides a framework for action to promote the adoption of low pesticide input pest management approaches, in particular Integrated Pest Management (IPM; EU 2009b). IPM, as described in the Sustainable Use Directive, is defined as a system based on three main principles: i) the use and integration of measures that discourage the development of populations of harmful organisms (prevention); ii) the careful consideration of all available plant protection methods; and iii) their use to levels that are economically and ecologically justified.

[3] Regulation (EC) No 1107/2009 concerning the placing of plant protection products in the market, Directive 2009/128/EC establishing a framework for Community action to achieve the sustainable use of pesticides, Regulation (EC) No 1185/2009 concerning statistics on pesticides, Directive 2009/127/EC amending Directive 2006/42/EC with regard to machinery for pesticide application.

Figure 2: Alt'Carpo net for pomefruits in Valence (France) (Photo: INRA Gotheron)

Figure 3: Inter-row hoeing of winter oilseed rape, as part of an innovative IPM solution for winter-wheat based rotations in Flakkebjerg (Denmark) (Photo: PURE)

Since the introduction of the concept in 1959, many studies have suggested that adoption of IPM principles provides environmental, economic and health benefits (Stern et al, 1959). Despite the various benefits expected from IPM, not all Utilized Agricultural Area in Europe[4] is cultivated according to IPM principles. Overall, while adoption of IPM is rather common in orchards and protected (greenhouse) production systems, it still remains largely marginal in arable and field crops. But according to the new European legislation (EU, 2009b), all professional users of pesticides should follow the general principles of IPM (already since 1 January 2014). European Member States have been asked to set up National Action Plans to support this objective. Notwithstanding, this legislative pressure, an immediate switch cannot be reasonably expected in the highly diverse crop production systems in Europe. During this transition phase, it is unclear how readily such Integrated Pest Management approaches and crop-specific strategies will be adopted, especially whilst knowledge and technology gaps still exist. Moreover, there is high heterogeneity in the National Action Plans and level of commitments of the Member States.

In this context, understanding drivers of change, and how rapidly a switch in the crop protection paradigm from conventional dependent to an IPM basis can be pragmatically achieved is of interest. Why would European farmers adopt such principles if there were no mandatory regulation? Even in the presence of readily workable IPM alternatives, why would farmers adopt them if they are most costly? In the event of higher production costs, will consumers be willing to pay higher prices for goods produced with such approaches? Would retailers be willing to create specific market segments for IPM products? Will insurers be willing to cover the potential risks linked to IPM adoption? Beyond mandatory approaches, to what extent should public money be used to promote IPM adoption? In the *de facto* interim, how should incentive-based policies be designed? Answers to these questions are beyond the scope of agro-ecology research in pest management, but are nevertheless central to the success of evolution of farming towards the sustainable use of pesticides. Here, the economics tool box can help address some of these questions.

[4] The terms Europe and European Union are used indistinctly in the text.

This article draws on a large body of research in economics of pest control and management and provides a reflection on a range of pertinent issues towards understanding the drivers of change in plant protection practices. A few authors have reviewed the existing research in economics of pest management and pesticide policies (Carlson and Wetzstein 1993; Sexton et al. 2007; Waterfield and Zilberman 2012). However, understanding the drivers of IPM adoption requires another step since IPM covers a large set of principles and is, by far, not solely limited to reducing pesticide use. Such exercises have already been performed in the US, where the US congress has supported IPM development, providing financial backing for large IPM programs since the seventies (McCarl 1981; Kogan 1998; Swinton and Day 2003). Consequently, most of the literature addressing the question of why some farmers adopt IPM, whilst others do not, predominantly concern US farmers, or, in particular, those in developing countries, where low input agriculture is the norm (Fernandez-Cornejo 1996; Fernandez-Cornejo 1998; Yong-gong and Guo-jun 2001; Mauceri et al. 2005; Sexton et al. 2007; Bonabana-Wabbi et al. 2012). By contrast, with the exception of crop-specific sectors (e.g. protected crops and fruit production), evidence for the extent and drivers of IPM principles adoption by European farmers remains incomplete (Bailey et al. 2009; Freier and Boller 2009; Sharma et al. 2009; Hillocks and Cooper 2012). In this article, we propose updated information as well as a selection of questions and literature relevant for the European context.

The target audience of this paper are the extension services and persons in charge of the design or local implementation of measures to support IPM adoption in the European Union, as well as farmers willing to understand the legislation behind the changes in their environment. The objective of the article is to contribute to the understanding of the factors underlying and directing farmer's adoption of new plant protection practices in general, and IPM in particular. This is certainly a prerequisite to predict farmers' expected reactions to different policy incentives, and the successful formulation of policies and extension services supporting the evolution of IPM adoption in the European Union. The article is structured in two sections. In section 2, we explore private incentives likely to incite IPM adoption. In section 3, we consider a possible rationale for government intervention, whilst simultaneously illustrating some of the practical challenges in the design and implementation of policies supporting the adoption of IPM based farming. Based on the review of these two aspects, we conclude in section 4 with the presentation of an analytical framework to understand the drivers of changes in farmers' pest management practices (Figure 3).

2. Private incentives for Integrated Pest Management adoption

In modern agricultural systems responding to market signals, private incentives are important drivers for the adoption of new technologies and practices. The profitability of a new technology for a given farmer is determined by the characteristics of the production technology itself (its impact on quantity, quality and costs), but also by a number of farm-specific factors, such as farm size, human capital, labour availability, financial constraints, access to information, new inputs and, importantly, markets (Feder et al. 1985; Goodhue et al. 2010). Here, we are interested in those factors likely to encourage European farmers to adopt IPM principles in the absence of mandatory regulation and specific policy instruments. They can be classified into three categories: cost effectiveness of IPM technology(ies), opportunities offered to IPM products in the market, and other non-financial and behavioural factors. Knowledge of such private incentives is important since it determines the need for, and type of public policies required, which are aspects developed in section 3.

2.1 Cost effectiveness of Integrated Pest Management technology

Overall, there is a lack of quantitative evidence on the potential of Integrated Pest Management to increase economic sustainability relative to non-IPM strategies under region- and crop-specific growing conditions. Indeed, data on the economic costs and benefits of IPM solutions are scarce, and even more so with consideration of the European context. Moreover, because Integrated Pest Management encompasses many principles and practices, as illustrated by the long list of general principles of IPM in the Annex III of the Sustainable Use Directive (EU 2009b)), assessing the cost-effectiveness of IPM and comparing its implementation across countries is challenging (Waterfield and Zilberman 2012). Moreover, producers often only adopt parts of the spectrum of IPM principles and practices suggested by research and extension services. There is high diversity of "IPM-based" practices, ranging from "almost no IPM" to "ultimate IPM". Furthermore, IPM is a dynamic and continuous process, were the different strategies part of IPM are very rarely simultaneously implemented. The assessment of the profitability of partial, or step-wise adoption, is rendered difficult by the fact that the efficiency of pest control is often obtained as a result of the complementarities of the different components within the IPM portfolio or spectrum (Zepeda et al. 2006).

The most comprehensive summary of producer-level economic evaluations of IPM programs to date was developed in the Unites States (Norton and Mullen 1994; Fernandez-Cornejo 1998). Although evidence in Europe is growing, albeit slowly, it is currently mostly restricted to ex-ante analysis based on expert judgment, and rarely on quantitative empirical evidence collected directly from field trials. The on-going PURE project financed by the European Commission FP7 program (Innovative crop protection for sustainable agriculture, www.pure-ipm.eu) aims, amongst other objectives, to produce this evidence with on-station and on-farm data, from six key European farming systems (winter-wheat based rotations, maize-based cropping systems, field vegetable crops, pomefruit, grapevine, and protected vegetables) through the evaluation of a range of candidate IPM solutions from intermediate (solutions easy to implement and scientifically validated) to advanced (solutions in the experimental stage). We here provide a summary of recent experience and data in Europe, although limited, on the cost effectiveness of IPM adoption.

Pelzer, Fortino et al. (2012) proposed a multi-attribute model (DEXiPM) to perform ex ante assessments of the sustainability of IPM in arable cropping systems, defined in a maize production context corresponding to the French region of Poitou-Charentes. This model highlighted differences between winter crop-based and maize-crop based systems. For the winter crop-based innovative system, economic sustainability was found to decrease for the

IPM approach compared to the conventional baseline. Higher labour costs, due to superficial tillage and crop monitoring, were recorded. However, systematic field observations for the monitoring of pests, weeds and disease populations, and treatment decisions based on thresholds defined according to local conditions, can help limit pesticide use to the actual minimal required dosage level, and therefore reduce input costs. Moreover, lower yields and lower selling prices were observed, due to reduced opportunity for alternative cash crops in the rotation. By comparison, for the maize-based system, the economic sustainability was found to be improved with IPM. The production costs are reduced with IPM compare to conventional (lower pesticide, fertiliser and irrigation costs), the yields are higher, but the selling price at the cropping system scale is lower due to the introduction of sunflower in the IPM crop sequence. Other results on ex-ante evaluation of more innovative IPM strategies for maize-based cropping systems have also been collected by Vasileiadis, Sattin et al. (2011). Interviewing experts (mostly advisors) in five European regions (Denmark, Netherlands, Hungary, Spain, and Italy), found that automatic weed monitoring, as well as longer term system monitoring, are expected to have a neutral economic impact. However, deployment of reliable cultivars, pest and disease forecasting models, early detection methods, precision spraying employing advanced Global Positioning System, as well as community-based decisions and information sharing, are all approaches that can result in a system net profit within a time frame of 3–4 years.

Focusing on another top fruit production system, Mouron, Heijine et al. (2012) proposed a comprehensive methodology (SustainOS) for evaluating the environmental and economic sustainability of region-specific IPM strategies in apple orchards from across 5 European regions (Switzerland, Germany, The Netherlands, France and Spain). Experts estimate that pesticide use can be reduced without reducing total yield or quality, but with considerable differences between countries. In some countries, IPM strategies were expected to increase total yield by up to 29%, and to increase the percentage of first class fruit by up to 20% compare to conventional strategies. But the use of IPM was predicted to result in economic disadvantages in some countries because some alternative measures are labour and capital intensive. The cost for alternative crop protection measures (such as a higher proportion of area with hail netting or enclosure netting) can be greater than the capital saved by reduced spraying. Furthermore, monitoring and training increase labour costs. Nevertheless, overall, in some of the regions and systems tested, higher yields compensated for increased costs.

Overall, the impact of IPM on cost depends not only on the impact of the adoption of IPM principles on pesticide use, but also on the cost of substitutes. Based on two different samples of French farms producing arable crops (in the departments of Meuse and Eure et Loire), Boussemart et al. (2012) showed that agricultural practices using less pesticide per ha are cheaper than practices using more pesticides, without increasing the costs due to the use of substitutes. In addition, they found cost dominance[5] to be a robust phenomenon across size and scope dimensions (Boussemart et al. 2011; Boussemart et al. 2012).

[5] Cost dominance of agricultural practices using less pesticide per ha means that the optimal cost frontier of the farms with lower pesticide use is below the one of farms with higher pesticide use (for farms within the same region with homogenous pedoclimatic characteristics). The cost frontier framework allows for eventual presence of technical and allocative inefficiencies in the data, and is therefore preferred to a traditional cost function.

Concerning substitution of chemical control with biological control, through their review of various studies, Bale et al. (2008) concluded that the cost–benefit ratio for biological control is highly favourable compared to chemical control. Similarly, McConnachie et al. (2003) reviewed several examples of successful applications of biocontrol, with high benefit-cost ratios. Again, such results are highly crop-dependant. Biological control is very well developed and highly profitable in protected environments for greenhouse crops, as well as in many orchards, offering solutions that work technically better than chemical control. In these systems, chemical control often failed because the most important pests had become resistant against the available pesticides. However, it is more difficult to make biological control work in in open fields and production systems with short crop cycle.

Quantitative evidence on the impact of the adoption of IPM principles on labour and management costs also remains limited. It is generally agreed that IPM strategies are time and information/knowledge intensive, compared to purely chemical control and more capital-intensive pesticide-based pest management strategy as used in conventional agriculture (Beckmann and Wesseler 2003; Waterfield and Zilberman 2012). Empirical studies in the United States have shown a significant negative impact of off-farm income on the adoption of IPM, confirming that opportunity costs of labour[6] are an important variable towards explaining rates of adoption. The higher the opportunity cost of labour, the less the farmer is likely to spend time on his farm, and therefore to engage in farming practices labour-intensive (McNamara et al. 1991; Fernandez-Cornejo et al. 1994; Fernandez-Cornejo 1998). Based on survey data from durian growers in Thailand, Beckmann et al. (2009) found that farms employing hired labour exhibited a lower adoption rate of IPM. In other words, the comparative advantage of IPM is higher under owner-operated pesticide application as hired labour is difficult to employ in many IPM tasks. Of course, the validity of this result in Europe will depend on the farm structure considered, as well as the qualification of farmers/agricultural operators.

The evaluation of the economic return of IPM adoption should not be limited to costs and yields effects. Indeed, crop protection also aims at maintaining output quality. It is recognised on one hand that pest damage can reduce the value of agricultural commodities when blemished (Yue et al. 2009), and, on the other, that chemical pesticides can have a quality-improving effect, especially for fruits and vegetables (Babcock et al. 1992). There is nevertheless evidence that IPM has no negative impact on output quality, measured for example as the percentage of 1st class fruits (Mouron et al. 2012).

Moreover, the evaluation of the economic return should not be restricted to one growing season. Indeed, benefits from IPM adoption can be delayed in time. For example, relying on the full portfolio of tools at the farmer's disposal -including biological control using natural predators of pests, mechanical control using specific tilling and cultivation techniques, as well as chemical control with pesticides, herbicides, and fungicides- and the systematic alternation between methods can help delay, or even prevent pesticide resistance build-up. This will be a source of cost saving, but only in the long run.

[6] The opportunity cost of labour is the best wage the farmer could get in a job outside farming.

We have summarized here recent studies in Europe on the cost effectiveness of IPM adoption. Available evidence accounts for the impacts on labour and input costs, as well as on yields, but is often restricted to the evaluation of single strategies part of IPM toolbox, with little guidance on the impact of their integration, the differentiation of the impact in the short and long run, and the potential variability in the results according to crops and agro-climatic conditions. Quantitative evidence on the cost-effectiveness of IPM in Europe is unfortunately too scarce to provide farmers with tools to predict the impact on their profits of IPM adoption. Apart from cost saving, one potential source of economic return consists in establishing new opportunities to sell IPM products compared to conventional products. In the next sub-section, we review the situation regarding the placement and recognition of IPM in the food market.

2.2 Market access and price premium with Integrated Pest Management

In general, differentiation of agricultural products, and its communication to the consumer, can provide growers with access to new markets, and, in some cases, price premiums for their product. However, the case of IPM is particular. Here, we review the situation regarding the placement and recognition of IPM in the food market nowadays, and how it is likely to evolve with IPM becoming a mandatory requirement for all agricultural products.

There is evidence that consumers are willing to pay more for reduced exposure to pesticide risk in general (Florax et al. 2005) and for organic products in particular (Torjusen et al. 2004). However it remains unclear whether products complying with other certifications (e.g. Integrated Pest Management) are recognized and positively valued by consumers. A limited number of studies have focused for example on the willingness to pay for non-organic apples, but certified by schemes including requirements in terms of crop protection (Loureiro et al. 2001; Marette et al. 2012; Bazoche et al. 2013). All these studies concluded that consumers' willingness to pay for such certified, but non-organic apples, is significantly higher than consumers' willingness to pay for conventional, and significantly lower than consumers' willingness to pay for organic apples. Although restricted to apples[7], these results suggest that IPM products can satisfy a niche market for consumers less willing to trade off price for higher environmental benefits compared with organic consumers. However, the price premium observed in these experiments, compared with conventional products, is rather low.

Beyond the fact that consumers are only moderately willing to pay more for IPM products, marketing Integrated Pest Management products is not an easy task, in the absence of official label at the European level. First, pest control based on economic thresholds and decision models, without a clear commitment regarding the reduction in overall pesticides use, appears difficult to communicate. Moreover, given the varieties of principles covered by the term "IPM", there is a risk of multiplication of labels, with quite different

[7] Apples market is often analysed because it corresponds to an important market share of fruit sales and because apple production relies heavily on pesticides.

interpretations and approaches. Not least, such a situation may add to the possible market saturation of certification schemes and labels and information overload for end consumers. Indeed, in this context, producers are encouraged to apply to different certifications for the same product in order to have access to different market segments (Canali 2011), resulting in increased production costs whilst simultaneously contributing to consumer confusion.

These different arguments may explain why retailers have been reluctant to create a specific market segment for IPM. Currently, in Europe, products grown using IPM are rarely identified as such in the market place for the end-consumers. However, retailers use IPM as a prerequisite for producers to deliver products to market segments with stricter environmental specification or access preferred supplier categories (i.e. the group of suppliers supermarkets will preferentially call upon) (ENDURE 2010). Complying with these general principles of Integrated Pest Management can lead producers to sell at higher prices but not always (Canali 2011). This is explicitly stated in the Global GAP business-to-business certification: "*Most people confuse global gap with higher prices, that is, they think that once you have been certified you can charge higher prices than the one who hasn't been. That is not very true. Yes, global gap opens up many markets for you, but it is not an assurance for higher prices. In most European countries, certain products are not allowed unless they are certified. So the benefits of global gap are more markets than more money. But then again if you push more products, you will enjoy economies of scale and make more profits*" (http://www1.globalgap.org).

Global GAP is one of this business-to-business certification integrating some principles of Integrated Pest Management as a requirement. The "Inventory of certified schemes for agricultural products and foodstuffs marketed in the European Union Member States" is the most up to date inventory of certified schemes for agricultural products and foodstuffs marketed in European Union Member States (Areté consultants 2010). Of the 427 certified schemes identified in this inventory, 56 voluntary schemes relate to integrated crop and integrated pest management principles, including both Business-to-business and Business-to-consumer schemes. They have been developed by the private sector, including both retailers and producers organizations. Fruits and vegetables are by far the crops mostly concerned by IPM certification. As a way of illustration, some of these various schemes are highlighted in Table 1.

Table 1: Examples of schemes certifying Integrated Pest Management in the European Union

Name of the scheme	Coverage	How is Integrated Pest Management included?
GLOBALG.A.P.	EU, extended to non-EUROPEAN UNION countries Business to Business (not	GlobalGAP is a private sector body that sets voluntary standards for the certification of agricultural products based on Good Agricultural Practices (GAP). It was initiated in 1997 by a number of retailers represented in the Euro-Retailer Produce Working Group. It is a pre-farm-gate-standard that

	directly visible for the consumers)	means the certificate covers the process of the certified product from before the seed is planted until it leaves the farm. The Global GAP crops module covers Integrated Pest Management, as well as traceability, propagation material, site history and site management, soil management, fertilizer application, irrigation/fertigation, plant protection products and equipment. The GLOBAL G.A.P. Database registers the assessment and certification data of more than 130,000 farms in over 120 countries.
Producción Integrada 	Spain Business to Consumer	Each Spanish region has developed his own scheme for integrated production, but since 2002, all regional schemes are covered by the "Real Decreto 1201/2002, de 20 de noviembre, por el que se regula la producción integrada de productos agrícolas." Integrated Pest Management principles are included in the "crop protection" chapter of "producción integrada". Integrated Production certified farms can receive agri-environmental payments. The surface registered account for 659 294 ha in 2010.
Certification environnementale des exploitations agricoles	France Business to Consumer	The French scheme of farms environmental certification was created in 2010. It is built around four themes: Biodiversity, Plant protection strategy, Management of fertilizer use, Water management. Farms can be certificated at three different levels: -Level One: fulfilment of the

		environmental requirements in cross-compliance. -Level Two: compliance with a set of 16 different criteria, among which some are related to crop protection. Among the indicators, some can reflect a certain level of Integrated Pest Management (eg. treatment frequency index, use of non-chemical alternatives to crop protection). Existing programs have received recognition on their equivalence with level 2 (eg. "Agriculture raisonnée" managed by the inter-professional association FARRE) -Level Three "High Environmental Value": It involves a formal agreement to achieve defined outcomes. The farmer can choose to be assessed according to four composite indicators related to biodiversity, plant protection strategy, fertilizer use, water management or two synthetic indicators (share of ecological focus area or permanent pasture in UAA and share of input costs in turnover).
LEAF	United Kingdom + 40 other countries in Europe, Middle East, South America and North Africa Business to Consumer	LEAF (Linking Environment And Farming) is a non-governmental initiative set up in 1991 with a view to develop Integrated Farming Management (IFM). Integrated Pest Management is an integral part of IFM. Farmers applying for LEAF certification must first have globalGap certification, plus extra control points on crop protection. In 2012, 357 761 ha were LEAF certified across the world, with 223 141 ha in UK (487 farms).
Fruitnet	Belgium, extended to Belgique,	Fruitnet is an example of private brand who has designed his own certification scheme, following the principles

	France, Spain, New-Zealand and South Africa Business to Consumer	described in Belgian law on integrated production in fruit production (Arrêté du Gouvernement flamand du 26 mars 2004).
IP SUISSE	Switzerland Business to Consumer	IPSuisse is a swiss certification scheme focused on Integrated Production. It includes three layers: general requirements for the farm (including legal requirements and requirements of the program "Proof of Ecological Performance" that sets minimum standards for direct payments), general requirements for biodiversity, security and training, as well as and product-specific requirements for 6 categories of products (cereals, colza, potatoes, fruits, cider and meat). For the biodiversity requirements, farmers get points when following some practices (eg. crop rotation, soil cover, limited fertilizer use, mechanical weeding, use of auxiliaries, ecological focus area…) and they need a minimum of points to be certified. In 2014, 20000 farms are certified: 15250 livestock farms, 4500 cereal producers (24000ha), 250 seed rape producers (950ha).

Note: Authors own elaboration. We have selected some schemes (non-exhaustive selection) from the list of certification schemes included in the "Inventory of certified schemes for agricultural products and foodstuffs marketed in the European Union Member States"(Areté consultants 2010). The information presented here is based on information collected on the websites of the different schemes.

With the new European legislation (mandatory compliance with the general principles of integrated pest management for all professional users of plant protection products) certification schemes need to evolve beyond general IPM practices, since, at least in Europe, voluntary certification schemes cannot certify practices corresponding to legal requirements (EC 2010). Therefore, even if the question has already been debated, there will be no official European official for IPM, contrary to what exists for organic farming.

Indeed, producer and retailer organizations willing to develop IPM voluntary certification schemes will have to include specific requirements, going further and beyond general IPM principles as defined in the Sustainable Use Directive (certifying the application of more innovative and crop-specific IPM approaches and practices).

Another, not unrelated but associated question, relates to the expected impact of the new legislation on prices and consumers' preferences. As mentioned, IPM has been, up until now, a requirement for market access imposed by retailers. Even if IPM adoption is akin to product differentiation, producers receive no price premium for IPM products. In Europe, adoption of IPM general principles is now a legal requirement imposed by the legislator (and no longer by retailers), but the expected impact is similar, i.e. no price premium for IPM grown products. According to basic economic theory, prices would increase only if large-scale adoption would result in higher production costs and lower yields at European level; or by a change in consumers' preferences. Using economic experiments, Biguzzi et al. (2014) found that the gradual reduction of shelf space for conventional tomatoes, following the implementation of the sustainable use directive, would benefit equally to organic and IPM tomatoes, whatever the prices. However, in their experimental study, they found that if conventional tomatoes totally disappeared, the winning market segment between organic and IPM would depend on the price difference between these products.

In this section, we have analysed the impact of IPM adoption on market access and price premium. In general, IPM products emerge as poorly recognised by the end-consumer, given the relatively few IPM labels on the supermarket shelves. Most certification schemes are business-to-business, where adoption of IPM practices is a requirement for market access. In this context, it is considered that the new legislation will not have a major impact on the market, only force producer and retailer organizations to redefine their certification schemes so that they include requirements that go beyond the legal ones. Finally it is worth mentioning that the evidence presented in sections 2.1 and 2.2 concerns merely the impact of IPM adoption on costs, yields and output prices and market access. As such, all these indicators concern the economic dimension. Recent advances in behavioural studies of farmers' decision making warns us against the exclusive use of pure economic rationality frameworks, supporting the inclusion of social, cognitive, as well as emotional factors towards the analysis of production decisions. In the next section, with this in mind, we look at the effect of attitudes on IPM adoption.

2.3 The role of farmers' attitudes

Behavioural factors and farmers' attitudes towards risk, innovation or the environment are likely to explain the deviation from an adoption decision purely driven by economic rationality. Such factors are important to take into account as they can impact farmers' responsiveness to policy instruments based on purely financial incentives.

First, we focus on the role of farmers' risk preferences. Pest and disease attacks constitute one of the biggest sources of risk in agriculture; especially because they are likely to provoke "catastrophic risk" (up to 100% crop losses). Not only can pests and diseases reduce yields, but they can also impact quality, therefore exposing producers to quality-based price risk. Consequently, risk is considered a major factor reducing the rate of adoption of new agricultural technologies (Marra et al. 2003). According to the conventional view, pesticides have been considered an important component in reducing the risk of yield loss and are commonly used as an insurance by risk-averse farmers (Mumford and Norton 1984). However, some results suggest that fertilizer and pesticides may, in fact, constitute risk-increasing inputs in some contexts (Pannell 1991; Horowitz and Lichtenberg 1993; Regev et al. 1997). Quantitative evidence on the impacts of the adoption of IPM principles on production risk are now old references and restricted to the US experience, and they have shown heterogenous results (Musser et al. 1981; Hurd 1994). Currenlty, and to the best of our knowledge, the only available information in the Europe is given in Mouron, Heijine et al. (2012), according to whom experts judge income variability (both due to the standard deviation of yield per ha and the standard deviation of the proportion of 1st class fruit) to be higher in IPM than in conventional European apple orchards.

In spite of the absence of convincing evidence that profit variability is significantly affected by IPM principles adoption, growers often perceive new practices as posing inherent risk (Musser et al. 1986). In this context, adoption of IPM can be clearly considered as risky, due to the novelty of some of the strategies part of the IPM toolbox, but also the knowledge or experience gap. Farmers can perceive as risky the decision to learn new plant protection methods, compared to the perceived certainties and experiences of the conventional production paradigm and the risk management potential offered by chemical control.

In this context, insurance represents a potential tool to encourage adoption of IPM principles (Feinerman et al. 1992; Mitchell 1999). Until now, there is a relatively low and slow uptake of crop insurance in Europe (compare to the US). Most insurance schemes do not appear well suited to alternative farming practices. For example, the insured party should prove that he has used all possible crop protection tools available in agriculture in order to be compensated for crop losses. Not using maximal chemical control and departing from conventional crop protection tactics could be qualified by insurers as a motive to refuse compensation. Recently, efforts have been made to take into account the specific insurance needs of organic farming. In this respect, the US Agricultural Risk Protection Act now takes into account organic farming specificities (Singerman et al. 2011; USDA 2013). Recently, some private insurance companies have started offering specific insurance policies for organic agriculture in Europe (eg. "Atout 5 bio" by Crédit Agricole, France). Therefore, conceptually, there is no real impediment as to why this could not be expanded to Integrated Pest Management. Insurance products designed for corn rootworm IPM users have been already developed under a collaboration between the U.S. Department of Agriculture's Risk Management Agency and the Agricultural Conservation Innovation Center (Cubie 1999). However, to date, we are not aware of any similar large-scale experience in the European Union, neither for IPM nor for integrated farming in general.

Beyond farmers' attitudes towards risk, there is evidence that attitudes towards health and environmental risk due to pesticide exposure can be key factors in adoption (Lichtenberg and Zimmerman 1999; Cuyno et al. 2001). Indeed, there is evidence that some farmers are willing to trade-off economic profitability for reduced health and environmental risk due to their farming practices. This would be in favour of IPM since IPM principles contribute to the reduction of environmental risks associated with pesticide use by encouraging the adoption of more ecologically benign control approaches and strategies. Several studies show that the environmental sustainability (as measured by indicators of resource use, water and soil quality, flora and fauna, Co_2 emission, etc.) of IPM is improved compared to conventional systems (Mouron et al. 2012; Pelzer et al. 2012). Moreover, as IPM approach includes the use of the most effective formulations and safest application technologies, and can result in fewer pesticide applications, health risks to agricultural workers and rural communities are minimized (Brenner et al. 2003).

Farmers' attitudes towards innovation are also important when it comes to adoption of new crop protection methods. They determine whether farmers know (about new techniques), be willing (to apply), be able (have the skills), be allowed (social component for change) and dare (to experiment) to apply new techniques.

This section discusses private incentives for Integrated Pest Management adoption, i.e. those factors likely to encourage European farmers to adopt IPM principles in the absence of mandatory regulation and specific policy instruments. Overall, there is lack of quantitative evidence on the potential of Integrated Pest Management to increase economic sustainability relative to non-IPM strategies related to European agro-ecosystems. However, there are little arguments against the fact the application of IPM general principles will represent for farmers the opportunity to increase returns via saving on costs. Until now, adoption of IPM practices has allowed producers to get access to specific markets, but did not guarantee any price premium. The new legislation is not expected to have any major impact on market organization, since it only transforms a requirement imposed by retailers into one imposed by the European legislator. It will only forces retailers and producers organization to revise their certification schemes and include requirements going beyond the legal ones. Finally, the behavioural factors briefly presented can explain why, even when alternative pest control methods are more profitable than chemical control, other external incentives can be required, at least during a transition period, towards IPM adoption. We further explore and expand on policy drivers in the next section.

3. Public policies to foster Integrated Pest Management adoption

While pest management decisions are made at the farm level, they can be influenced or constrained by public policies. The question is whether the private incentives presented in the previous section are sufficient to lead to a rapid and wide adoption of IPM principles or whether there is room for government intervention. Through the Sustainable Use Directive, the European Union has decided to rely on regulation and has made the adoption of IPM general principles mandatory for all European farmers. In the first instance, it is interesting to understand the rationale behind policy intervention in crop protection. Secondly, we present and evaluate the usefulness of a number of potential options available within a policy "toolbox". While we rely on the economic literature on the role of policy drivers in adoption of new practices in general, we always have in mind the actual context in the European Union and illustrate some of the practical challenges in the design and implementation of such policies in the current European Context.

3.1 Why is public intervention necessary in crop protection?

Crop protection in agriculture presents various cases of market failure (Waibel 1993). Market failures are situations where individuals' pursuit of pure self-interest leads to results that are not efficient, i.e. that deviates from the socially optimal pest control practices maximizing the net benefit to society including consumers, farmers, plant protection products producers, as well as the environment. Market failure remains one of the most influential arguments for public intervention. Having in mind the market failure framework, we illustrate here why and to what extent public policies have a role and are necessary to promote IPM adoption in Europe.

3.1.1 Crop protection and externalities

While farmers are private entrepreneurs, taking their business decisions individually, outside agents are impacted unintentionally, both positively and negatively, by pest management practices. Externalities associated with crop protection decisions are numerous, with impacts at diverse levels: farm workers, soil and water contamination, degree of pest pressure and resistance and impact on the quality and safety of food (Sexton et al. 2007). These externalities are usually not taken into account in the market in the form of higher prices for pesticides, or lower prices for pesticide-intensive crops. Moreover, farmers usually do not take into account the costs of compensating other agents for possible environmental or health damages due to their farming practices for which they can be held liable. This implies that the signals received by farmers when they have to take decisions relative to crop protection are inefficient. Whereas farmers can have private benefits from IPM adoption in the form of increased profits or non-pecuniary advantages (as describe in section 2), many of the benefits of the adoption of IPM principles are also in terms of avoided negative externalities, benefiting to society at large. Extra incentives, either through mandatory or voluntary approaches, are therefore required to make the time and financial investment associated with IPM adoption attractive and economically viable, particularly in a transition period as currently being experienced in Europe (Waterfield and Zilberman 2012). The design of policy instruments should be such that farmers integrate the social benefits from IPM adoption in their objective function when taking decisions about pest management.

3.1.2 Crop protection, landscape ecology and coordination failure

Coordination failure arises when a group of farms could achieve a situation more desirable for society but fail to do so because of the absence of coordinated decisions, although each individual understands the challenges and recognises the need for action. For example, since pest populations migrate across farms and wider areas, coordinated pest control actions among farmers confronting with the same pest pressure is an optimal IPM approach. It allows prevention of pest population spread, damage and resistance build-up at both farm/field and landscape levels. Recent results in landscape ecology have shown that IPM activities designed at the landscape/regional scale can offer greater benefits than IPM at field level because of the positive externalities from one farm to the other (McKee 2011) (e.g. pheromones insect traps (Tscharntke et al. 2007)). However, regional IPM strategies are considered most costly to implement as they require additional societal acceptance, coordination and cooperation among farmers (Brewer and Goodell 2012) and different forms of incentives are necessary to encourage their development at such scales.

Given this clear role for public policies to promote IPM adoption, we present in the next section the instruments currently used in Europe and illustrate some of the practical challenges in their design in order to address these market failures.

3.2 How can public policies encourage IPM adoption?

Over the years, a number of instruments have been proposed to influence farmers' decisions with regard to crop protection. They can be classified in three categories: regulatory instruments, information dissemination measures and incentive-based instruments. Here, we discuss the advantages and limits of these instruments for the promotion of IPM adoption, both in the transition period of implementation of the Sustainable Use Directive, and in the long run.

3.2.1 Regulatory instruments

With regulatory instruments, public authorities mandate and control the environmental performance to be achieved or the technologies to be used by farms. In recent years, the European Union has released several regulations and directives[8], either targeting IPM directly or with potential indirect impacts on IPM adoption.

Different pieces of European and national legislations have been developed over recent years to regulate pesticide use. While they do not target IPM adoption, they may indirectly favour the use of alternative pest control methods by constraining the use of certain active substances and plant protection products. Firstly, the criteria for the approval of active substances are regulated at European Union level, while authorisations to place plant protection products on the market remains the responsibility of individual Member States (EU 2009c). Secondly, the European Union also imposes Maximum Residue Levels of pesticides permitted in food products (EU 2005). Maximum Residue Levels are the upper legal levels of a concentration for pesticide residues in or on food, or feed, based on good

[8] From the Treaty on the functioning of the European Union Article 288 : "A directive shall be binding as to the result to be achieved upon each Member States to which it is addressed but shall leave to the national authorities the choice of form and methods." It can be distinguished from regulations which are self-executing and do not require any implementing measures. Directives normally leave member states with a certain amount of leeway as to the exact rules to be adopted.

agricultural practices and to ensure the lowest possible consumer exposure. Finally, European Union legislators have also specified requirements with which machinery for pesticide application must comply before being placed on the market and/or put into service (EU 2009a).

In addition, as part of the pesticide package, the Sustainable Use of pesticides Directive 2009/128/EC explicitly mentions IPM, from where two fundamental types of provisions are distinguished: obligations imposed to all the professional users of pesticides in the European Union, and, secondly, obligations imposed at Member State level. Concerning professional users, the mandatory character of IPM is reflected in Regulation (EC) No 1107/2009 concerning the placing of plant protection products on the market (Article 55). Therein it is stated that plant protection products shall be used properly, and proper use includes the compliance with the general principles of integrated pest management defined in annex III of the directive, which shall apply at the latest by 1 January 2014 (EU 2009c). Concerning the obligations imposed at Member State level, according to article 14 of the Sustainable Use Directive (EU 2009b), Member States have to describe in their National Action Plans how they ensure that the general principles of IPM are implemented by all professional users by 1 January 2014. Furthermore, beyond the general principles of IPM, Member States shall establish appropriate incentives to encourage professional users to implement crop or sector-specific guidelines for integrated pest management on a voluntary basis.[9]

Among the practical challenges in the implementation of the Sustainable Use of pesticides Directive, there is the fact that the introduction of two levels of responsibilities (at the individual level for every professional user, and at the Member State level) resulted in dilution of responsibilities and increases the need for coordination. Indeed, there is a risk that, if crop specific guidelines are not available at Member State level, then making adoption of general IPM principles mandatory at individual level will not have a major impact. Moreover, another challenge relies on the fact that individual Member-States are responsible for the crop-specific guidelines, but international organizations already have taken on board part of this task. For example, major activities of the International Organisation for Biological Control (IOBC) include "the practical implementation of biological and integrated controls for pests and diseases of particular crops" (IOBC-WPRS web). However, the guidelines available still need to be refined to be of practical use for producers, as well as updated with the latest scientific advances concerning the efficiency of different plan protection strategies and their integration.

Beyond legislation related to pesticides use, it is also important to consider the full regulatory environment on agriculture, as pest management decisions are inevitably impacted by the agricultural policy (Sexton et al. 2007). The Sustainable Use Directive is

[9] The development and implementation of Member State National Action Plans are still on-going and it is difficult to assess, at this stage, levels of consistency / variability between Member States or expected or anticipated levels of success with respect to overall IPM adoption (this would be subject of a future analysis from a period of application and experience, unable to be addressed effectively at this stage, and as such is beyond the current scope of this review).

consistent with the objective of the European Common Agricultural Policy (CAP) to promote more sustainable farming practices. When the Sustainable Use Directive is finally implemented in all Member States, and the obligations directly applicable to farmers clearly identified through their respective National Action Plans, the relevant parts of the Directive should be included in the system of cross compliance (EU 2013a). The exact timing will depend of the proper implementation on the ground. Under this so-called cross compliance system, Member States impose penalties in the form of reduction or exclusion of CAP support in case of non-compliance of individual farmers.

A similar approach was retained in Switzerland, where, in 1996, Swiss citizens voted for an amendment to the federal constitution to include the principle of multi-functionality and sustainability for the Swiss agricultural sector. As a result, it was decided that farmers should enrol in a national programme on ecological production and respect the guidelines of either integrated or organic production in order to qualify for direct payments. At that time, the requirements to comply with integrated crop/livestock production were: management of crop rotation, cultivation of meadows, ground covering, closure of nutrition cycles, phosphorus and nitrogen balances, use of pesticides only if damage thresholds are reached, ecological set-asides on at least 5 % of arable land, buffer strips along surface water, hedges and forest (Swiss Confederation 1996). In 2005, target objectives were achieved with 90% of the cultivated land in integrated production and 10% certified as organic. Nowadays, organic farming receives extra compensation on top of direct payments (ecological direct payment) but integrated production is not rewarded since it became the norm. Rather, the Swiss Confederation supplements farmers' incomes with direct payments on condition that a "Proof of Ecological Performance" is made (Swiss Confederation 2013). Besides direct payments, farmers profit from joining the national programme by being able to market their produce under Swiss-wide unified labels for either integrated production (IPSuisse (Table 1)) or organic production (Bio Suisse).

Following a similar path, European Policy makers have chosen to make adoption of IPM general principles mandatory at farm-level. The penalties in case of non-commitment (defined by the Member States in accordance with Article 17 of the Sustainable Use Directive) together with the cross compliance regime act as an incentive for farmers to adopt IPM. But Member States are also required by the Article 14 of the Directive to "establish appropriate incentives to encourage professional users to implement crop or sector specific guidelines for integrated pest management on a voluntary basis". Despite the fact that a mandatory approach has been chosen, it is recognized that there are adjustment costs to the new legal requirements. This may create the needs for incentive-based instruments, likely to compensate part of these costs. Moreover, to allow the application of general principles of IPM from all professional users, an increase in advisory services has been identified as a central resource to assist practioners with the necessary technical and economical adjustments, inherent to IPM adoption. We develop in the next section the role of information dissemination measures and support to farmers' training.

3.2.2 Information dissemination measures

Persistent barriers to the adoption of new farming practices include, among other factors, limited availability of and access to production and market information (Atanu et al. 1994;

Lohr and Salomonsson 2000; Dimara and Skuras 2003). The objective of training and advisory systems is first to raise awareness and to stimulate farmers' interest in alternative methods of pest management (Schreinemachers and Tipraqsa 2012), then to provide farmers with the necessary tools to implement crop-specific guidelines for IPM (Braun et al. 2006). Educational programs are a useful method for approaching the complex problem of pesticide regulation, especially when there are uncertainties regarding the efficacy or environmental effects of alternatives crop protection methods and when the integration of different approaches is the solution (Goodhue et al. 2010).

Information measures important for IPM adoption include free or subsidized pest management advisors, independent from, and complementary to, the advice provided by companies or commercial entities selling plant protection products (Waterfield and Zilberman 2012). Moreover, advisory services should contribute to the implementation of farmers groups in order to share the costs associated with IPM and to better manage spill overs at landscape-scale (e.g. through cooperatives). Demonstration farms are considered very valuable measures for both knowledge exchange between research, advisors and farmers and for the efficient dissemination of IPM methods to other farmers. Demonstration activities serve as proof of concept and are often highly appreciated within farming communities (Bailey et al. 2006).

The Sustainable Use Directive places considerable emphasis on such measures. European Union Member States have to provide professional users with information and tools for pest monitoring and decision making, as well as advisory services (Article 14). Measures for risk reduction and information about IPM are listed in the training subjects (Annex I to the Directive). In the National Action Plans recently released by Member States, training measures for farmers, advisors and pesticide distributors, as well as the establishment of advisory services and dissemination measures have a critical and central role (Table 2). Many countries already have mandatory farmer training and now include IPM issues in their existing schemes. A novel component here is that the training of advisors or trainers will become mandatory in most countries, in order to ensure that up to date technical information and approaches are disseminated (Dachbrodt-Saaydeh 2013).

Table 2: Mandatory training for different groups according to the implementation of the Sustainable Use Directive

Country	Training mandatory for the advisors (since/from)	Training mandatory for the agricultural professionals (since/from)
Bulgaria	YES	YES (2013)
Czech republic	YES (2004)	YES (2004)
Germany	YES (1987)	YES (1987)
Denmark	NO	YES (1993)
Estonia	YES (2013)	YES (2000)
Spain	YES (2012)	YES (2015)
Finland	NO	NO
France	NO	NO
Ireland	NO	NO
Italy	YES (2015)	YES (1995)

Lithuania	YES (2012)	YES (1995)
Latvia	YES (2004)	YES (1995)
Malta	NO	YES (2004)
Netherlands	YES (1996)	YES (1996)
Poland	YES (2013)	YES (1996)
Portugal	YES (2006)	YES (2006)
Romania	YES	YES
Slovakia	YES (2014)	YES (2010)
Sweden	NO	YES
Slovenia	YES (1998)	YES (2001)
United Kingdom	NO	YES (1986)

Note: In the National Action Plans recently released by Member States, training measures for farmers, advisors and pesticide distributors, as well as the establishment of advisory services and dissemination measures have a critical and central role. The information was compiled based on the National Action Plans by S. Dachbrodt-Saaydeg (2013). The year corresponds to the year where training have/will become mandatory for the advisors or the agricultural professionals. Many countries already have mandatory farmer training and now include IPM issues in their existing schemes. A novel component here is that the training of advisors or trainers will become mandatory in most countries, in order to ensure that up to date technical information and approaches are disseminated.

Such IPM Training activities could be organized and expanded within the framework of the CAP Farm Advisory Services (FAS) since it is foreseen that Member States should provide advice to farmers through the Farm Advisory System on the proper use of plant protection products, and in particular compliance with the general principles of integrated pest management. Advisory services offered to farmers can be free or not, face-to-face, trough brochures, internet, seminars .... If the advice is not free, countries can decide to include training in the list of possible rural development measures[10] and farmers applying to such measure would receive compensation for the cost of training (EU 2013b). Such compensation are part of the incentive-based instruments, developed in the next sub-section.

3.2.3 Incentive-based instruments

While European policy makers have decided to rely on mandatory approaches to reach the adoption of the general principles of IPM by all farmers, there is still some room for incentive-based instruments. Indeed, the Sustainable Use Directive recognizes that incentive-based instruments can play a crucial role in the achievement of objectives relating

[10] Under the new rural development policy (Article 15 Advisory services, farm management and farm relief services), it is explicitly stated that support can be granted in order to help farmers benefit from the use of advisory services for the improvement of the economic and environmental performance as well as the climate friendliness and resilience of their farms, and to promote the training of advisors.

to the sustainable use of pesticides and encourage their use, while stressing that individual Member States are free to include them or not in their National Action Plans. More precisely, the Sustainable Use Directive explicitly refers to the establishment of incentives to encourage the implementation of crop or sector-specific guidelines. Moreover, given that adoption of general IPM principles does not necessarily mean reduction in pesticide use, incentive-based instruments can be used as a complement to influence farmers' behaviours in that direction.

Incentive-based policies usually refer to taxes and subsidies. Taxes or subsidies can be used to modify the private incentives to the adoption of different pest management methods when users fail to take into account all the externalities of their pest control practices (Rademaekers et al. 2011). The principle is rather simple and straightforward: if the action of one agent provides a beneficial service to society at large, then the individual may need to be compensated (subsidy) in order to provide the socially optimal level of the service. If, on the contrary, the actions cause harm to society, then the individual may need to be charged, or taxed, for those actions to maximize collective social welfare.

The times of subsidies, or reduced value added tax rate(s) for pesticides, is now passed (Schreinemachers and Tipraqsa 2012). The elimination of environmentally harmful subsidies was the first step taken to encourage the rationalization of crop protection (Withana et al. 2012). Some European countries have even taken a further step by taxing pesticide use and subsidizing adoption of alternative crop protection methods. Here, we review some of these initiatives and present their advantages and limits in promoting IPM adoption.

3.2.3.1 Tax on pesticide use

In theory, a tax on the use of a pest control treatment constrains producers to take into account all the positive and negative externalities associated with the use of the treatment. With a well-designed tax system, pesticides are used up to the point where using more pesticides will be more costly (including also environmental damages) than beneficial (Zilberman and Millock 1997b). Moreover, taxes play the role of innovation stimulation, through their impact on farmers and crop protection industries' willingness to find alternative practices (EUROSTAT 2007). It is therefore a useful complement to regulation on IPM adoption. Lastly, tax revenues can cover the costs attached to their collection, and potentially be used to finance research and extension services. Nevertheless, it should be noted that an effective tax will raise limited benefits if the agents adapt their behaviours so as not to pay the tax.

Although, in theory, taxes are appealing, a number of practical challenges limit their feasibility (Zilberman and Millock 1997a). A well-designed tax should take into account all the external effects of pesticide use. It therefore requires a lot of data on biological processes (Zilberman and Millock 1997a), especially given that the magnitude of these external effects varies not only with the level of pesticides applied, but also with the manner, time, and space of application. According to environmental taxation theory, the tax rate should vary from farm to farm, according to the location of the farm and the application rate and technology. Such a flexible taxation scheme has never been implemented since it would be overly costly to formulate and difficult to implement and enforce (Falconer and Hodge 2001). The few European Union countries who have introduced pesticide taxes rely on a simpler approach (Baumol and Oates 1988): they have defined an objective of reduction in pesticide use and have fixed the pesticide tax such as to attain it, with limited consideration of the marginal damage function and marginal costs of reduction[11] (with the exception of the recently reformed pesticide tax in Denmark). Table 3 summarized the existing pesticide taxes in Europe.

Table 3: Pesticide taxes in EU

Country (date of implementation)	Tax rate, base and payers	Complementary measures	Outcomes and limits
Sweden (1984)	Fixed amount on every kg of active ingredient (3.3 EUR per kg of active substance), corresponding in average to a 5-8% tax rate on retail price. Tax paid by manufacturers and importers.	The tax revenues finance activities of the pesticides programme including education and inspections of farmers.	The doses per hectare have remained stable since the tax was introduced in 1984, but the tonnage of active substance has decrease by more than 60%, and the aggregate risk factor has also declined by over 70%.
Denmark (1996)	Since 1998, the tax rate was equal to 54% of retail price for insecticides and 33% for herbicides, growth regulators and fungicides. The tax scheme has been revised in 2012 to take into account the load on environment and human health of each pesticide product.	Around 75% of tax revenues are returned to the farmers through reduced land taxes. The remainder is used to finance various actions such as farmers' education campaign, compensation to farmers for maintaining buffer zones, tighter pesticide approval procedures…	The treatment frequency index (TFI) has been at approximately the same level as before the tax was adopted (2.5), whereas the objective was to reach 1.7. Moreover, Danish pesticide use has increased by around 50% from

[11] Marginal cost of reduction corresponds to the increase in cost when pesticide use is reduced by one unit, or one percent. Marginal damage corresponds to the increase in damage due to the increase by one unit or one percent of pesticide use. In theory, both should be taken into account to design an optimal environmental tax.

	The products with the least desirable properties (the higher load) are now more expensive. Tax paid by manufacturers and importers.	An "Integrated Pest Management points system" is currently developed as a tool to be used by advisory services to promote the use of Integrated Pest Management and to be able to measure the progress.	2002 to 2011. Given that the tax rate was not differentiated according to product toxicity until recently.
Norway (1998)	€/ha according to product toxicity class. A new tax system was implemented in 1999. It introduced differentiation according to human health and environmental criteria. The tax is area-based with a base rate of about 3.4 euros per hectare. This is then multiplied with a factor (0.5 to 9) for one of the five tax classes, to give the tax for each plant protection product. Standard area dose (g or ml per hectare) is used to convert tax per hectare to tax per kg or litres of product.		
France (2000)	The General Tax on Polluting Activities (TGAP) has been applied to "antiparasitic products for use on farms, and other similar products" from 2000. But since 2008, the TGAP was replaced by a fee on diffuse agricultural pollution collected by public	The proceeds of the tax are distributed among the water and waste-treatment-plant operators. The French National Action Plan (Eco-Phyto) is mainly based on an awareness and education campaign, the development of a real-time warning	The tax rate is too low and the tax revenues cover less than the sole cost of treating pesticide contaminated water for drinking.

	water agencies from pesticide distributors, according to the quantity of active substance sold by products distributors in France and the toxicity level. The rate is equal to 2 €/kg for dangerous organic substances and 0,90 €/kg for mineral substances (OECD 2011). Pesticides were suppressed from the list of products benefiting from a reduced VAT rate in 2011. VAT applied is now 19.6%.	system against pests and the banning of a number of substances used in pesticides.	

Note: We have summarized here the information on the existing pesticide taxes in Europe, based on the following sources: (Aubertot et al. 2005; PAN Europe 2005; Pedersen et al. 2011; Rademaekers et al. 2011; Miljøstyrelsen 2012; Nordic Association of Agricultural Scientists 2012)

3.2.3.2 Payments for IPM adoption

Agri-environmental measures (AEM) have been implemented within the European Common Agricultural Policy with the aim to encourage farmers to protect and enhance the environment on their farmland, when the cost of doing so outweighs the benefits at farm level. Such payments provide a compensation for the costs associated to the learning phase of adoption, or the riskiness of the new practice. Subsidies also constitute a payment for the services provided by early adopters to the community: early adopters will gather experiences and information that will benefit other farmers interested in adoption.

Under the Common Agricultural Rural Development Policy, European Union Member States have to select and specify the AEM most relevant to their particular farming systems and environmental conditions. In the programming period 2007-2013, some Member States supported integrated production in general (e.g. Austria, Portugal), while others targeted the implementation of integrated production in specific sectors (e.g. horticulture in Brandenburg, Germany), or under measures dealing with food quality schemes (e.g. Poland). Other agri-environmental measures have aimed to decrease the adverse impact of pesticide use but did not necessarily promote IPM. For example, compensation for riparian buffer zones along streams and lakes have been offered to Danish farmers in order to protect the aquatic environment and to prevent leaching of pesticides to ground water (Christensen et al. 2011).

Agri-environment-climate payments can cover only those commitments going beyond mandatory standards. Therefore, Member States will not be permitted to support adoption of IPM general principles via AEMs after 2014. Rather, Member States willing to design AEMs targeting crop protection will have to focus on the support to sustainable agronomic practices going beyond the mandatory requirements (e.g Integrated Crop Management (PAN Europe 2010)).

One risk of such payments is to provide incentives for the adoption of single and crop-specific practices. Rather, they should be cautiously designed to encourage the adoption of IPM as a system, at the farm or even landscape-scale. According to Ehler and Bottrel (2000), the IPM policy experience in the US has failed because the approach was restricted to the adoption of some specific techniques, without the required integration between them. Current agri-environmental schemes in Europe also tend to have this shortcoming (e.g. support to crop rotation in France and Germany, support to mechanical weeding in Belgium). Taking advantage of the on-going reform of the European Common Agricultural Policy and the evolution of national Rural Development plans, policy instruments could be improved towards the promotion of IPM as an integrated approach, beyond the current support to disparate single techniques.

We have described here the various European regulations, information dissemination measures and incentive-based instruments likely to influence farmers' decisions with regard to crop protection and favour the adoption of Integrated Pest Management. Some of them have already been implemented in some Member States, especially with the objective to reduce pesticide use. But IPM adoption by all European farmers is a different objective. IPM adoption being a dynamic and continuous process, were the different strategies part of IPM are often implemented step-by-step, a more pragmatic approach to fit with the nature of IPM is to rely on a combination of these instruments.

Concerning the tax on pesticide use, we know that price elasticity of pesticide use is very low and therefore very high tax rates are needed to achieve reduction (Falconer and Hodge 2001; Jacquet et al. 2011; Skevasa et al. 2012). Moreover, price elasticity is also likely to decrease with efforts to reduce chemical control, therefore the tax rate should increase when the quantity of pesticide reduces. Therefore, given that such tax rates are rarely politically acceptable, a pesticide tax, as a stand-alone measure, is ineffective and should be complemented by other financial incentives and extension services (Falconer and Hodge 2000). For example, taxes that differentiate according to toxicity are effective only if farmers are informed on the use of low-toxicity substitutes (Skevasa et al. 2012)[12].

[12] Pesticides are categorized in toxicity classes in the European Union's classification system, regulated by the Dangerous Substances Directive (Directive 67/548/EEC) prior to 2016, and the regulation (EC) No 1272/2008 of

Moreover, it should be noted that whereas pesticide taxes are useful to encourage pesticide use reduction in a more flexible way than bans on active substances, they do not provide incentives to adopt IPM as a systematic and/or holistic approach. Efficient training on the various crop protection strategies available, and on their integration is necessary to promote crop protection strategies going beyond the reduction of pesticide use.

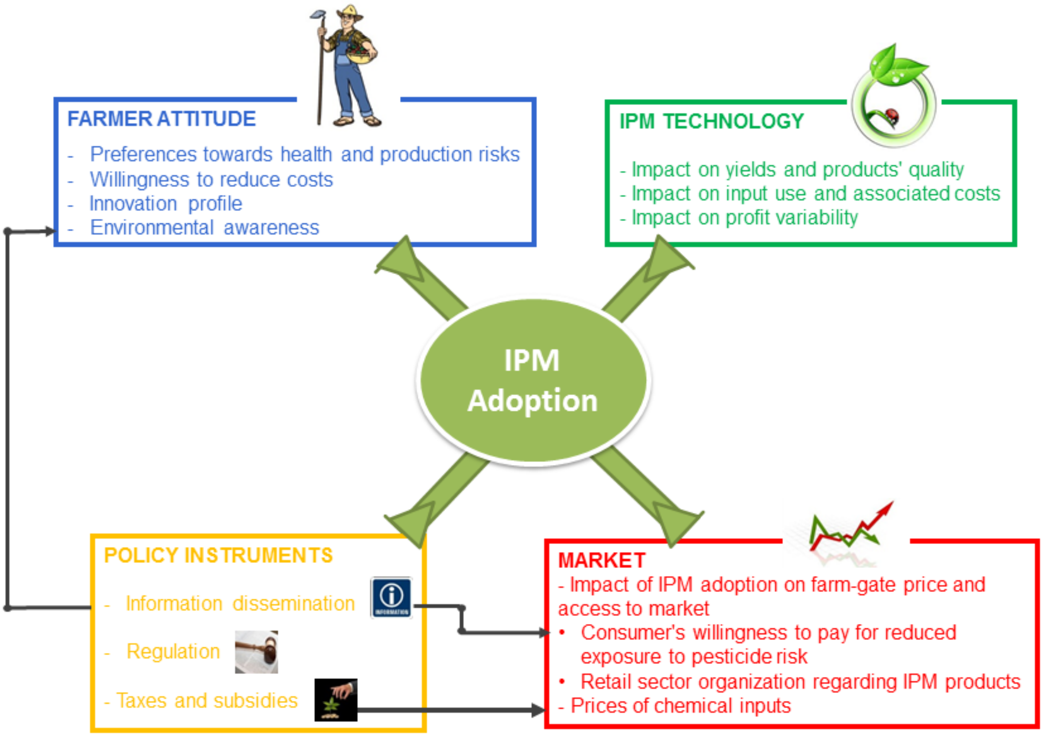
The effectiveness of these policies likely to foster IPM adoption will differ according to each farmer characteristic and farming system, not least crop. While the approach retained in Europe consists in accepting that IPM general principles are applicable to all crops and across all Member States, farmers' reaction to policy instruments can be highly diverse. For example, since fruits producers have a very low share of their income coming from agricultural policy payments, they are more dependent on farm-gate prices they receive for their products, compare to arable farmers for example. Therefore, they may be more likely to adopt practices for which they will get a price premium, or at least new market access. Large-scale adoption of IPM, beyond the mandatory general principles, may therefore only be achieved through crop-specific and region-specific programs (Vasileiadis et al. 2011; Mouron et al. 2012).

Conclusion

In this review, we have tried to decipher and understand the pertinent drivers of changes in farmers' pest management practices and their expected reaction to different policy incentives targeting IPM adoption, in a context of legislative change in the European Union. Indeed, a good understanding of the spectrum and relevance of private incentives is a first step towards the design of more efficient policies. Based on the results from the literature and considerations discussed above, we propose a framework summarizing the incentives for Integrated Pest Management adoption (Figure 3). It includes four main categories of drivers: First, the cost effectiveness and impact on risk of IPM technology, the market drivers (access to market and farm-gate price for IPM products, input prices) and farmers' attitudes towards innovation, the environment and health risks correspond to the private incentives for adoption. The last box recaps the policy instruments likely to further support adoption, when private incentives are too weak, especially in a transition period, or when the market sends wrong signals in the presence of external effects of farmers' crop protection decisions.

the European Parliament and of the Council on classification, labelling and packaging of substances and mixtures from 2016.

Figure 3: Incentives for Integrated Pest Management adoption – general framework



Note: We have summarized here the main drivers of Integrated Pest Management adoption. While IPM adoption is a farm-level decision, depending both on the technology itself and farmers' attitudes towards this technology, there are also external factors likely to trigger adoption such as market prices, society preferences, and policy instruments creating the incentives towards widespread adoption. We highlight the interrelations between the components with the arrows. For example, consumers' willingness to pay for reduced exposure to pesticide risk are influenced by information dissemination measures.

We briefly summarize here the main results. We have reviewed the incentives linked to the cost-effectiveness of IPM technology. While adoption of IPM principles can provide positive economic benefits for farmers in the form of reduced costs, large variations according to the specific IPM practice under study, the crops and local conditions, are expected. Unfortunately, experience in Europe is too limited to provide general guidance to farmers on the most technically and economically efficient IPM strategies at present. As pointed-out in the Sustainable Use of Pesticide Directive, crop-specific guidelines are still to be developed. Concerning market incentives, it is clear that products grown using IPM methods are currently rarely identified as such in the European market place. Up to now, certification schemes including IPM requirements have functioned rather as market entry requirement, or a condition for selling in specific market segments. Early adopters did not get a premium for IPM products, unless in the cases where compliance with IPM approach allowed to reach higher market segments. In this context, it is not expected that mandatory adoption of IPM principles will have a strong impact on the output markets. We have also considered the importance of non-financial incentives likely to foster IPM adoption, such as concern for reducing profit variability, as well as environmental and health risks. It is now well recognised that attitudes are clue, especially when the profitability of a new technology is not well known.

In the European context, a clear argument still remains for the role of public intervention in promoting IPM adoption. The main arguments supporting public intervention in crop protection include the fact that signals received by farmers when they have to take decisions relative to crop protection are inefficient, given the existence of externalities, as well as the need for coordinated action at landscape-level, in order to reach maximum benefits from IPM. Adoption of IPM general principles has been made mandatory for all farmers through European Union legislation but we have shown in this article that incentive-based and information dissemination measures are useful complementary instruments.

Incentive-based instruments impact the profitability of IPM by increasing pesticide costs through taxes and subsidizing farmers for the specific production practices whose social benefits are larger than individual private ones. Information dissemination should complement such incentive-based measures to modify farmers' attitudes towards risk (e.g. by the design or support of adequate insurance products), innovation (e.g. by the empowerment of extension services on IPM) and the environmental and health consequences of their decisions. Importantly, adoption of alternative farming technologies does not depend only on farmers, but often requires changes in the whole system. Thus, there is also a role for the State to promote recognition of IPM across the whole agri-food sector, including retailers and end-consumers. Policies for IPM promotion should search for high integration between all such instruments.

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Annex C: Mandatory Integrated Pest Management in the European Union: Experimental insights on consumers' reactions

Coralie Biguzi, Emilie Ginon, Sergio Gomez-y-Paloma, Marianne Lefebvre, Stephan Marette, Guillermo Mateu, Angela Sutan, *Consumers' preferences for integrated pest management: the case of tomatoes*, presented in EAAE conference 26-29 August 2014, Ljubljana and submitted to Food Policy.

Abstract

An experiment was conducted to analyse consumers' reaction to the transition towards Integrated Pest Management (IPM) as the standard in European farming. Preferences for fresh tomatoes produced by three different production systems of 189 French consumers were analysed: IPM, conventional and organic. Results indicate the existence of strong substitution opportunities between IPM and organic tomatoes. IPM sales will benefit from the withdrawal of conventional produces from the market only if there is a significant reduction in the price of IPM compared to organic and/or an important increase in the shelf space dedicated to IPM. Raising awareness on the impact of consumption choices on future prices of the produces has only a limited impact in this context. While information on IPM guidelines increases IPM products purchases, providing extra information on residue levels in IPM tomatoes has no further impact on consumers' choices.

JEL code: C91, D12, Q13, Q18

Keywords: Integrated Pest Management, Organic, Tomatoes, Sustainable Use of pesticides Directive, Multinomial probit, Laboratory Experiment

Acknowledgments and disclaimer:

The survey on which this paper is based was funded by the IPTS, JRC-European Commission in the context of the project "Consumers' willingness to pay for Integrated Production: experimental design and data collection", PO 153580. However, the views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission. The authors would like to thank the partners of the FP7-PURE project for supporting the initial idea. We would especially like to thank Christine Poncet (INRA) for contributing to the elaboration of the information on the different types of tomatoes disclosed to participants.

M. Lefebvre, S. R. H. Langrell and S. Gomez y Paloma formulated the original question. The experiment was designed by E. Ginon, S. Marette, and A. Sutan with the help of M. Lefebvre and G. Mateu and programmed by G. Mateu in z-Tree. The sessions were organized by C. Biguzzi with the help of E. Ginon, G. Mateu, A. Sutan and H. Saysithideth. M. Lefebvre performed data analysis and wrote the first version of the manuscript. All authors provided feedback on previous versions of the manuscript and contributed to the final version. M. Lefebvre was responsible for overall coordination.

Introduction

Many scientific and regulatory claims have been made over recent years about the potential harmful effects of pesticide intensive farming systems for both environment and human health. The search for sustainability of agriculture has led to explore potential alternatives to crop protection and to the adoption by the European Union in 2009 of the Sustainable Use of pesticides Directive (SUD). This directive provides a framework for action to achieve a sustainable use of pesticides and to promote the adoption of low pesticide input pest management. Integrated Pest Management (IPM) has been retained as one of the possible approaches to achieve low pesticide-input pest management in the EU, together with organic farming (EU 2009b). As described in the SUD, IPM is a system based on three main principles: i) the use and integration of measures that discourage the development of populations of harmful organisms; ii) the careful consideration of all available plant protection methods, including: biological, mechanical and chemical control; and iii) the use of chemical control to levels that are economically and ecologically justified. This possible application of chemical pesticides helps to bypass the problem of low yields linked to organic farming, leading to more affordable products. As a result, IPM has been described as "a middle course between the extreme constraints of organic farming standards and the increasingly unacceptable pursuit of intensive agriculture" (Wibberley 1995), and as "a third way, both economically realistic and environmentally beneficial" (Morris and Winter 1999).

Whilst consumers' willingness to pay (WTP), and preferences for organic food products, is now well recognised, the knowledge of the IPM market is much more limited. Do consumers recognize the benefits of this "third way"? Are consumers willing to pay a price premium, and, if so, what is the quantum of this premium compared to organic? Widespread adoption of IPM by farmers will depend, among other drivers, on the profitability of this crop protection strategy (Lefebvre et al. 2014). Predicting the proportion of consumers in the market who will try IPM products, when other products are available, is a key question, and within this context, this article aims to analyse consumers' preferences for Integrated Pest Management, when conventional and organic produces are also available.

Marketing Integrated Pest Management products for the end-consumer is neither a simplistic nor straight forward task for several reasons. First, pest control based on economic thresholds and decision models appears difficult to communicate since there is no clear commitment regarding the reduction in overall pesticides use. Moreover, given the varieties of principles covered by the term "IPM" (as illustrated by the list of general principles of IPM in the Annex III of the Sustainable Use Directive), there is a risk of multiplication of labels, with quite different interpretations and approaches. Not least, such a situation may add to the possible market saturation of certification schemes and labels and information overload for end-consumers. Producers are encouraged to apply to different certifications for the same product in order to have access to different market segments, resulting in increased production costs whilst, simultaneously, further contributing to consumer confusion (Canali 2011). The large number of different logos indicating environmental sustainability already available in the market raises the question of whether their associated messages are successfully conveyed to consumers. Previous research has shown that most existing logos fails to convey their message, which suggest the need to provide consumers with adequate information on environmental sustainability (Ginon et al. 2014).

These different arguments may explain why retailers have been reluctant to create a specific market segment for IPM. Currently, in Europe, products grown using IPM are rarely identified as such in the market place for end-consumers. However, retailers use IPM as a prerequisite for producers to deliver products to market segments with stricter environmental specification or to be in the group of suppliers supermarkets will preferentially call upon (ENDURE 2010). Complying with these general principles of Integrated Pest Management can lead producers to sell at higher prices (but not always) (Canali 2011).13 As a consequence of this market organization, market data on consumption of IPM products at household level are inexistent. As a result of the scarcity of market data for new or non-labelled products, the burgeoning literature on food choices relies increasingly on experimental data, using non-hypothetical and incentive compatible choice methods to elicit consumers' preferences and WTP (Becker et al. 1964). Several of these studies have focused on "green" or "eco" products, obtained from more sustainable farming systems, with the aim of distinguishing market segments and estimating their market potential at premium prices.

It has been previously shown that consumers are willing to pay more for reduced exposure to pesticide risk in general (Florax et al. 2005) and for organic products in particular (Torjusen et al. 2004; Janssen and Hamm 2014). However, it remains unclear how products complying with other environmental certifications are valued by consumers. While several studies have focused on estimating WTP for food products with environmental attributes others than organic, research on IPM is much more limited. Marette et al. (2012) studied the effect of a new label signalling apples that only use a few pesticides (corresponding to a 50% reduction in the pesticide use compared to conventional apples). The authors decided to name this alternative ''Few Pesticides'' rather than ''Integrated Pest Management'' in order to make the low-quantity of pesticides explicit to participants. Doing so, they have hidden part of IPM complexity, which is nonetheless an important feature to understand this market. Bazoche et al. (2013) elicited consumers' WTP for apples to which are attached different kinds of certification concerning pesticide use, including IPM. Here, the focus was placed on the impact of information provided to consumers concerning pesticide use, with control for sensory characteristics. Together, both studies suggest that IPM can satisfy a niche market for consumers with different preferences on the trade-off between price and pesticide reduction.

[13] This is explicitly stated in the Global GAP business-to-business certification, which includes requirements concerning integrated crop management: "Most people confuse GlobalGAP with higher prices, that is, they think that once you have been certified you can charge higher prices than the one who hasn't been. That is not very true. Yes, global gap opens up many markets for you, but it is not an assurance for higher prices. In most European countries, certain products are not allowed unless they are certified. So the benefits of Global GAP are more markets than more money. But then again if you push more products, you will enjoy economies of scale and make more profits" (http://www.globalgap.org/uk_en/index.html, accessed July 2013).

Our experimental study further contributes to the understanding of consumers' preferences for IPM, when conventional and organic products are also available, using the example of fresh tomatoes. Very few studies have focused on vegetables whereas vegetables have high market share within organic consumption and concentrate a lot of effort in IPM research (van der Velden et al. 2012). Although all the available evidence on preferences for tomatoes production systems to date focuses on organic (Weaver et al. 1992; Yue et al. 2009; Ali Bashir 2012; Mesías Díaz et al. 2012), this study compliments the available literature by capturing in the laboratory the evolution of the legislative environment, according to which all growers in the European Union should follow IPM guidelines (or be certified organic) from 1st January 2014. While previous studies have focused on the estimation of WTP for IPM, we analyse how the market share will be redistributed across IPM and organic production when conventional products are withdrawn from the market. To do so, we investigated how IPM tomatoes consumption would be influenced by a reduced availability of conventional products and an increase in shelf space dedicated to IPM. The experimental design accounts for the potential impact of relative prices on consumers' preferences. We also analyse the impact of providing to consumers extra information on the characteristics of the final products (focusing on pesticide residue levels), in addition to the description of the production system. Overall, the results allows for the provision of recommendations for effective marketing and pricing decisions of IPM products and for improving the consumer responses to the new legislative environment on IPM.

The paper is structured as follows; Section II presents the method employed and data generated. Results are presented in section III, and discussed in section IV. Section V provides conclusive remarks.

Data and Method

Participants

The experiment was conducted at the Laboratory for Experimentation in Social Sciences and Behavioral Analysis (LESSAC) in Dijon, France, with 189 non-expert food shoppers (129 female and 60 male), aged between 22 and 75. The sample of consumers was recruited from the general population using different procedures: half of the participants were randomly selected from a panel of volunteer consumers having participated in other studies at LESSAC and half were recruited thanks to posters in the market of Dijon city and by word of mouth. Among the persons willing to participate, priority selection was made of those buying tomatoes in autumn/winter in order to ensure they will be interested in buying tomatoes during the experiment.14 Participants were asked to fill out a detailed questionnaire on their socio-demographic and consumption characteristics at the end of the experiment. Whereas we cannot claim the sample is representative of the French population, it is, however, relatively balanced in terms of age, gender and consumption

[14] In the recruitment email, respondents were asked which vegetables they were used to buy at this period of the year (autumn) in a list of ten vegetables.

habits (Table 1). A total of ten sessions, of less than 90 minutes each, were organised during November 2013. Participants were randomly assigned to each session, ensuring the socio-demographic characteristics of the participants were not significantly different in the different sessions.

Table 1: Socio demographic characteristics and consumption habits of the participants

	Mean	St Dev	Min	Max
Female (%)	0.68	0.47	0	1
Age	39.48	14.85	22	75
Weekly consumption of tomatoes in winter (kg)	0.77	1.08	0	13
Weekly consumption of tomatoes in summer (kg)	2.20	1.71	0	10
Price usually paid for a kg of tomatoes (€/kg)	1.98	0.74	0	6
Share of organic tomatoes in total consumption (%)	0.26	0.29	0	1
Consumers never consuming organic tomatoes (%)	0.43	0.50	0	1
Consumers only consuming organic tomatoes (%)	0.04	0.19	0	1

Experimental design

The experimental design focused on three main variables. First, we investigate how the purchase of IPM tomatoes is influenced by the availability of conventional and organic products, and by the shelf space dedicated to IPM. The choice set was simplified to three production systems: IPM, conventional and organic tomatoes. We decided to include conventional and organic produces in the choice set because IPM is often seen as a third way between these two types of production. Second, the impact of providing extra information on the characteristics of the final products to consumers (focussing on pesticide residue levels), in addition to the usual description of the production system, was analysed. Lastly, the potential impact of relative prices on consumers' preferences was also assessed.

Each participant took part in one session composed of 10 rounds. Product availability, information available to participants and prices varied across rounds, as described in Table 2. At the beginning of each session, the participants received 20 Euros as a participation fee (Figure 1). In each round, each participant could choose the type and the quantity of tomatoes in Kilograms he wanted to purchase, with a minimum of 0.1kg.[15] It was possible to buy only one type of tomato in each round, among the five, three or two types available (there are three types of production systems, but with three types of conventional tomatoes in the first rounds, therefore a total of five types of tomatoes). At the end of the session,

[15] We wanted to avoid the status quo bias, resulting in a too high frequency of non-buyers.

each participant randomly drew one round out of the ten, and purchased the type and quantity of tomato chosen in the round drawn at the price specified. With this mechanism, each of the ten choices can be considered as a real purchase decision (Lusk and Schroeder 2004; Michaud et al. 2013).

The participants played the experiment individually and electronically following the experimental procedures. The experiment was programmed and conducted with the software z-Tree (Fischbacher 2007). Participants could see the types of tomatoes available and their respective prices on the computer screen and had to enter the quantity and type of tomatoes they wished to buy. Efforts were undertaken to make the experiment similar to a real buying situation. Instead of pictures or images, real tomatoes were used as product stimuli. The tomatoes were arranged on a table and participants were encouraged to view them during the experiment.

Figure 1: An experimental session illustrated

Prices

To analyse the impact of prices on choices, the prices of the different tomatoes across sessions and in the different rounds was varied. In the two first rounds, the tomatoes were priced according to reference prices. The reference prices were those observed in retail contexts (supermarkets) the week before the experiment (autumn prices) for the consumers participating to sessions 1, 2, 3, 6, 7 and 8. For the other participants, the reference prices corresponded to the price of tomatoes in summer (cheaper than in autumn). Then, two other price lists were tested in the other rounds. The difference between the prices of organic and IPM tomatoes was increased compare to real prices in price list 2 and was reduced in price list 3. The full list of prices is available in annex C and the price list associated to each round is specified in Table 2.

Moreover, the impact of an innovative pricing mechanism that accounts for the potential impacts of demand on producers' willingness to adopt more sustainable farming practices was tested. By increasing their demand of organic or IPM products, consumers can encourage their production, and in the medium run, prices of IPM and organic products may decrease when supply increases. We refer to this mechanism as the "price elasticity mechanism". In half of the sessions (sessions 6 to 10), the participants received the following information at the beginning: "If many of you choose to buy organic or IPM tomatoes, the prices of these tomatoes will decrease for the participants of the other sessions".[16] More precisely, the experiment was configured as follows: if the market share of IPM (organic) is higher or equal to 70% in round t and session X, the price of IPM (organic) is reduced by 20% in round t of the next sessions, compare to the prices in annex C. For the other sessions without the price elasticity mechanism, prices were those indicated in annex C.

Information on the production system and extra information on residues

Given the difficulty to present Integrated Pest Management guidelines to the end-consumer, we wished to test whether providing extra information on the characteristics of the final products, focusing on pesticide residue levels, in addition to information on the production system and crop protection strategies, were useful to promote IPM. In the experiment, participants were able first access to information on the technical specifications of the production system of each type of tomatoes. Then, from round 4, they could access extra information on the properties of the final product in terms of residue levels. From round 7, the complete information was disclosed to all participants to ensure measurement of the net impact of the other treatment variables (reduction in the shelf-space dedicated to IPM), assuming all consumers are informed. The content of this information is presented in annex A.

Successively revealing information to participants with regard to various characteristics of the product under study is a common design feature of food choices experiments (Marette et al. 2012). Most of the time, information is displayed to all participants and data are

[16] The design can be interpreted as a modified voluntary contribution mechanism. In the traditional voluntary contribution mechanism, each member of a group of potential beneficiaries of the public good decides simultaneously on a portion of its initial endowment to contribute to a group account. Here, the contributions to the public good do not benefit directly to the group but are transferred over time to a future group (inter-temporal transfers). Moreover, we combine the voluntary contribution mechanism with supply and demand conditions in the market for a private good. Here, the "public good", provided thanks to individual contributions, is a reduction in the price of sustainable products for next generations.

analysed assuming that all the information provided is processed to make informed decisions. Here, in contrast, participants had to click to have access to the information, i.e. they are only given the option to view information (as in Hu et al. (2006)). Voluntary access to information better captures a real shop situation where consumers have to actively look for information (either on the label or on the internet). Here, extra information was introduced sufficiently early in the experiment to account for the potential diminished attention to new information at the end of the experiment. The experiment focuses on the impact of providing extra information. We therefore did not rely on a between-subject design where some participants would have access to information on the production system while others have the information on residue levels, nor tested order effects.

Shelf space dedicated to IPM

In order to capture the evolution of the legislation on crops pest management, the shelf space[17] dedicated to conventional tomatoes during the experiment was reduced. At the beginning, participants were able to purchase fresh tomatoes from the conventional production system of three varieties, one type of IPM tomato and one type of organic. This captures the current situation where conventional farming remains the norm and conventional tomatoes occupy a large shelf space (3/5). Then, by reducing the number of different conventional tomatoes available for sale, the shelf space of IPM and organic tomatoes increases. In the last rounds, conventional tomatoes are not available and organic and IPM tomatoes equally share shelf space. We provided to participants explanations on the justification for the changes in the products available before the changes (messages in annex B). Moreover, in each session, the order of presentation of the different types of tomatoes was modified on the computer screen to help avoid position bias. Five different orders were tested over the ten sessions.

[17] The shelf space corresponds to the amount of space for one product in a store.

Table 2: Experimental design – description of the 10 rounds

Rounds	1	2	3	4	5	6	7	8	9	10
Produces available										
Conventional (Round)	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO
Conventional (Large Tomatoes-On-Vine A)	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO
Conventional (Large Tomatoes-On-Vine B)	YES	YES	YES	YES	YES	YES	NO	NO	NO	NO
Organic (Large Tomatoes-On-Vine)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
IPM (Large Tomatoes-On-Vine)	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Available information (see Annex A)										
Production system	NO	u.r	u.r	u.r	u.r	u.r	YES	YES	YES	YES
Characteristics of the final product	NO	NO	NO	NO	u.r	u.r	YES	YES	YES	YES
Prices (see Annex C)										
Price list	Ref	Ref	2	3	2	3	2	3	2	3

Note: u.r. = upon-request

Method for data analysis

In order to measure the impact of the different treatment variables on consumption choices, two approaches were relied upon.

First, the market shares of each type of tomato across rounds and sessions, using non-parametric tests, were compared. The market share of product j in round t is defined as the total quantities of product j purchased in round t by all participants divided by the total quantities of tomatoes bought in round t (all types of tomatoes).

Second, a multivariate probit model was used to help explain individual choices in the different rounds by alternative-specific attributes and consumer-specific variables.

The theoretical framework for analysing the choice of tomatoes can be cast in a random utility model. Formally, consider a consumer i from a sample of N consumers who has to choose a type of tomatoes from a feasible set defined by $\mathrm{j} = 1,2,3$ alternatives, namely, conventional (1), IPM (2), and organic (3). We assumed that each consumer attaches a utility value U_{ij} to each type of tomatoes depending on personal perception of alternative-specific attributes η_{ij} and consumer-specific factors h_i. Utility derived by an individual who chooses tomatoes of type j can be written as:

$$U_{ij} = \mathrm{U}(\eta_{ij}, h_i) \ \ \forall j = 1,2,3$$

In this model, a consumer chooses the type of tomatoes that maximizes his or her utility. Let D_{ij} denotes a discrete choice variable taking the value of 1 if a consumer chooses type j and zero otherwise. For exposition, a utility maximizing consumer will choose the first alternative only if the following inequality holds:

$$D_{i1} = 1 \ if \ U_{i1} > U_{ij}, j = 2,3$$
$$D_{i1} = 0 \ \ otherwise$$

and the corresponding probability that a consumer i chooses the first alternative can be expressed as:

$$P_{i1} = \Pr(U_{i1} > U_{i2} \ and \ U_{i1} > U_{i3})$$

Although the utility a consumer derives from choosing a particular type of tomatoes is not observable, some of the characteristics of the consumer and attributes of the alternatives are. The utility that a consumer obtains from alternative j can then be represented as:

$$U_{ij} = \mathrm{V}_{ij} + \epsilon_{ij} \ \forall j = 1,2,3$$

Where $\mathrm{V}_{ij} = \delta_j \mathrm{X}_{ij}$ is the representative utility, X_{ij} is a vector of observed variables relating to the alternatives and the individuals, ϵ_{ij} captures other unobserved factors that affect utility, and δ_j is a vector of unknown parameters.

We assume that ϵ_{ij} has the density function $f(\epsilon_i)$ where $f(\epsilon_i) = f(\epsilon_{i1}, \epsilon_{i2}, \epsilon_{i3})$ and has the mean vector equal to zero with the following corresponding variance-covariance matrix:

$$\Omega = \begin{pmatrix} \sigma_{i,1}^2 & \sigma_{i,12}^2 & \sigma_{i,13}^2 \\ \sigma_{i,12}^2 & \sigma_{i,2}^2 & \sigma_{i,23}^2 \\ \sigma_{i,13}^2 & \sigma_{i,12}^2 & \sigma_{i,3}^2 \end{pmatrix}$$

To avoid making the IIA assumption, and following Hausman and Wise (1978), we applied the multinomial probit (MNP) model, which allows for the error correlations along with the estimated coefficients. According to Alvarez and Nagler (1998), MNP estimates are more accurate than those of Multinomial Logit as it does not assume IIA.

In estimating the MNP model, not all J sets of regression parameters and elements of the variance-covariance matrix Ω are identifiable (Train 2003). Since our interest was to compare utilities across types of tomatoes, the variance of IPM tomatoes ($j = 2$) is normalized to one as the base alternative. For identification, we also normalize the variance of conventional tomatoes ($j = 1$) to one as the scale alternative.

Results

Descriptive analysis of market shares

Participants bought on average 0.70 kg of tomatoes in each round. This quantity corresponds to the average weekly consumption of tomatoes in autumn/winter declared by the participants in the post experiment questionnaire. Moreover, only between 10 and 13 participants per round choose the minimum quantity (0.1Kg). These two elements confirm participants' overall interest in buying tomatoes during the period of our study and the fact that the experiment is perceived as a real purchase opportunity.

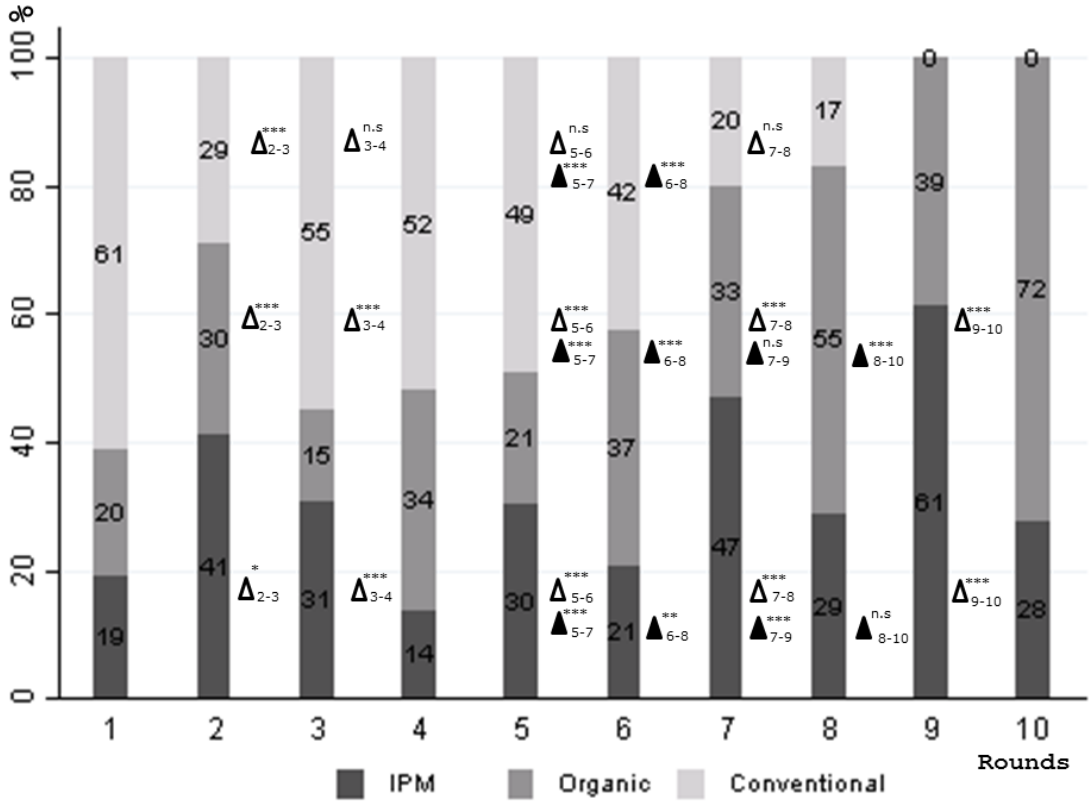
We focused the analysis on the type of tomatoes chosen with limited attention to quantities. Indeed, the quantity of tomatoes purchased was not significantly different across rounds (Skillings Mack statistics = 7.222, p-value=0.6140) (Chatfield and Mander 2009). However, participants have purchased different type of tomatoes in different rounds. The Skillings Mack statistics shows that the differences in the quantity purchased of each type of tomatoes were statistically significant across rounds (IPM: Skillings Mack statistics = 114.293, p-value=0.000; Organic: Skillings Mack statistics = 137.048, p-value=0.000; Conventional: Skillings Mack statistics = 218.033, p-value=0.000). Only 13 participants (6.88%) made the same choice during the ten rounds. Among them, ten always chose organic tomatoes. These ten consumers declared to consume on average 72.5% of organic in their real life tomato consumption. They exhibited strong preferences towards organic and they seemed to be less influenced by the treatment variables in the experiment.

Impact of the between-subject design variables

We observed a mostly non-significant impact of the between-subject variables. First, the quantities of conventional, IPM and organic tomatoes bought in the round 1 are not significantly different across sessions with different order of presentation of the products. Moreover, the market share of IPM tomatoes averaged over all rounds was equal with summer and autumn prices (33%). However, given that the price premium for organic tomatoes is lower in summer, the market share of organic tomatoes is higher in summer (39% vs 33% in autumn), at the expense of conventional tomatoes (28% vs 35% in autumn). Last, the price elasticity mechanism has an impact only in the first round. In round 1, in the sessions with the mechanism, participants purchased significantly less conventional tomatoes and significantly more IPM tomatoes (at the 1% level), while the quantities of organic tomatoes are the same with and without the mechanism. But in other rounds, no significant differences were observed between the quantities of conventional, IPM and organic tomatoes bought by the participants of the sessions with and without the mechanism. Moreover, the 70% threshold for the market share of organic or IPM tomatoes necessary to trigger the price elasticity mechanism was never reached in any of the rounds or sessions. This suggests that informing participants that their choices will impact future prices had a low impact, at least not sufficient to reduce future prices.

Therefore, data of all the sessions (with the different order of presentation of the products, with autumn and summer prices, and with and without price-elasticity mechanism) were pooled for the analysis of the other study variables. We systematically verified that similar conclusions were reached when analysing the data separately in the different sessions. Market shares in the different rounds for all ten sessions are presented in Figure 2.

Figure 2: Market share of IPM and organic and conventional tomatoes by round (n=189, all 10 sessions)



Note: Δt-t'ns denotes non-significant difference, Δt-t'* denotes significant difference at 10%, Δt-t'** denotes significant difference at 5% and Δ t-t'*** denotes significant difference at 1% as tested by the Wilcoxon test for comparing paired sample choices Qijt and Qijt', with Qijt the quantity of tomatoes of type j chosen by participant i in round t. The white triangles correspond to the measure of the impact of prices, while black triangles correspond to the impact of the shelf space dedicated to IPM.

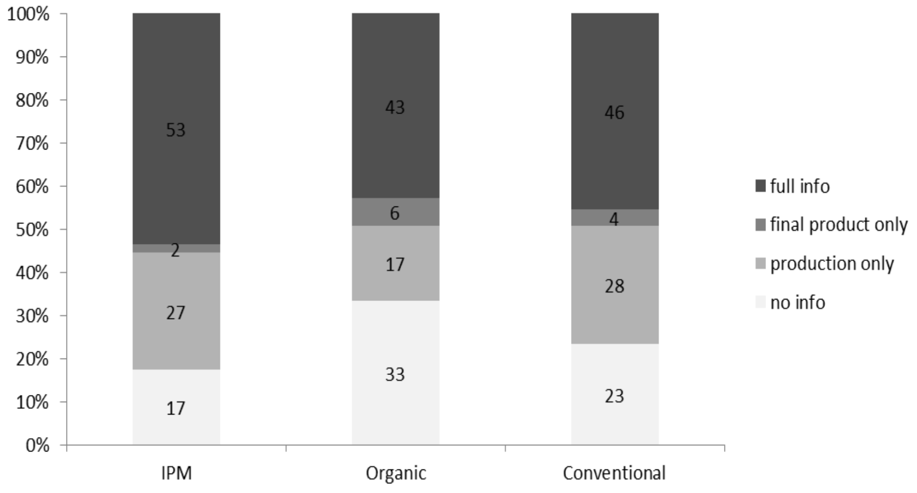
Impact of relative prices

The market share for conventional tomatoes significantly increases between rounds 2 and 3 (from 29 to 55%), when IPM and organic tomatoes become relatively more expansive compared to conventional tomatoes (Figure 2). This substitution impacts more the organic market (30% in round 2 to 15% in round 3) than IPM (41% to 31%). This is explained by the fact that there is a larger price difference between IPM and organic tomatoes in round 3 than round 2. Between rounds 3 and 4, organic tomatoes win market share at the expense of IPM tomatoes (with the market share of conventional tomatoes remaining stable). IPM market share drops from 31% to 14% and the quantities of IPM tomatoes purchased are significantly lower, due to the smaller price difference between organic and IPM tomatoes in round 4 than in round 3. The same result is observed in rounds 5 and 6, 7 and 8 and 9 and 10.

Impact of information

Most of the participants exhibited interest in getting more information about the products. In the last round before full disclosure of the information to all participants (round 6), only 23% of the participants did not read any information on conventional production system, 17% on IPM and 33% on organic farming (Figure 3) Participants were clearly less interested in information on organic farming, which was expected given the overall good knowledge of organic agriculture in the general public. This also suggests that participants are curious and willing to learn about unknown production systems such as IPM. Among the participants looking for information, most of them have showed interest in both level of information (on the production system and the characteristics of the final product in terms of residues). Only a small percentage of participants only looked at the information on the residues without reading the information on production.

Figure 3: Level of information of participants before full disclosure of the information to all participants (round 6)



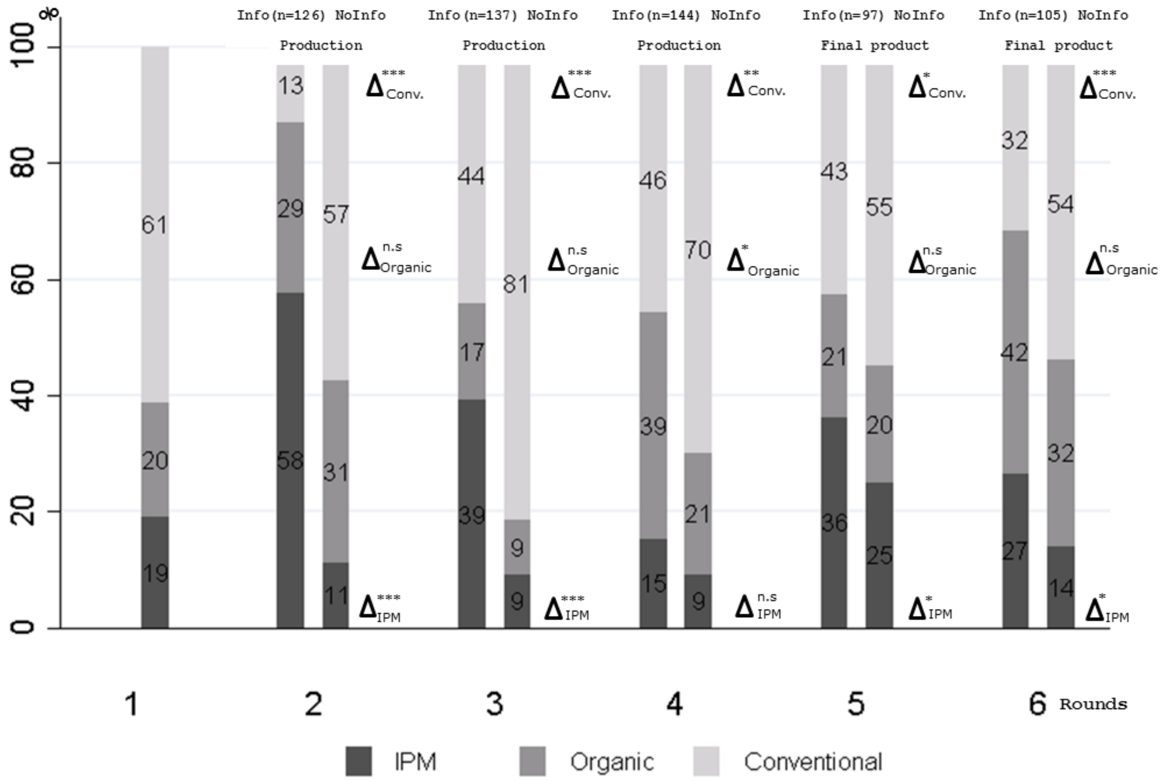
In order to measure the impact of information on consumption choices, we separated the sample into two groups: participants who chose to access information on the IPM production system were classified as "Info" and those who did not look at the information on IPM as "NoInfo".18 Participants who received information on IPM in round 4 but did not read any extra information on the residue levels in IPM tomatoes are classified as "NoInfo" in rounds 5 and 6. The two participants who were not interested in the information on the production systems, but did read the information on the residue levels, were classified as "NoInfo" in rounds 2 to 4, but as "Info" in rounds 5 and 6. Figure 4 represents the market shares of IPM, organic and conventional tomatoes by round, separately for those participants informed and not informed about IPM.

In round 1, in the absence of any information on the different tomatoes, the market share of conventional tomatoes was highest (61%), corresponding to shelf-space dedicated to them (3/5). Moreover, even if organic tomatoes were the most expensive, the market share of organic tomatoes was slightly higher than that of IPM tomato. A strong and positive impact of the information on the production system disclosed in round 2 was observed. Indeed, in round 2, the market share of IPM was significantly higher for participants informed on the IPM production system. Informed participants bought significantly more IPM tomatoes and significantly less conventional tomatoes. The same result held with another price list in round 3. But when the difference between the prices of organic and IPM tomatoes was low (round 4), the impact of being informed on IPM on the quantities of IPM tomatoes purchased was not significant. Rather, some of the informed participants switched to organic tomatoes, probably due to the low price difference.

When extra information on the characteristics of IPM product in terms of residues was available, the informed participants bought significantly more IPM tomatoes than those non-informed (rounds 5 and 6). However, comparing choices across rounds with the Wilcoxon test (paired sample), we observe that, for the informed participants, the quantities of IPM tomatoes bought did not significantly increase in round 5 compared to round 3 (p-value=0.51) and round 6 compared to round 4 (p-value=0.10). It suggested that the extra information on the residues levels had only a limited impact in convincing new consumers to switch to IPM, given that some of the consumers had already switched as a result of the information on the production system.

[18] We have verified results are similar if we use two alternative criteria to define the informed consumers: i) informed participants are those having read the information for the three types of tomatoes, while the non-informed are those who did not read all the information; ii) informed participants are those having read information on at least one of the production systems and non-informed are those who did not look at any information). Given that the paper focuses on how to communicate on IPM, we decided to present results relative to being informed or not about IPM.

Figure 4: Market share of IPM, organic and conventional tomatoes by round and level of information



Note: Δ^{ns} denotes non-significant difference, Δ* denotes significant difference at 10%, Δ ** denotes significant difference at 5% and Δ*** denotes significant difference at 1% as tested by the Mann–Whitney two-sample test comparing the distribution of the quantities of tomatoes of each type chosen by the sample of informed participants and the sample of non-informed participants. The size of the sample of informed participants is indicated in parenthesis (n=).

Impact of the shelf space dedicated to IPM

The reduction in the shelf space dedicated to conventional tomatoes after round 6 had a significant impact on the quantities of IPM and organic tomatoes bought (Figure 2 black triangles). More precisely, in terms of market shares, it benefited equally organic and IPM tomatoes. The market share of organic rose from 21% in round 5 to 33% in round 7 and from 37% in round 6 to 55% in round 8, and for IPM it rose from 30% in round 5 to 47% in round 7 and from 21% in round 6 to 29% in round 8. When conventional tomatoes totally disappeared from the market after round 8, it benefited more IPM than organic when the price difference between organic and IPM was large (round 9). The market share rose from 47% in round 7 to 61% in round 9 for IPM and from 33% in round 7 to 39% in round 9 for organic. However, when the price premium for organic is low (round 10), even if organic tomatoes are more expensive than IPM tomatoes, the suppression of conventional tomatoes benefited mostly the organic market (from 55% in round 8 to 72% in round 10).

In order to better understand how these different factors interact to impact consumers' decisions, we analysed individual choices between the different tomatoes with an econometric model.

Econometric analysis

We present the estimates from the multinomial probit model of the determinants of consumer choice of tomatoes in Table 3 and the marginal effects in Table 4.. The interpretations are made on the marginal effects results.

Female consumers are 8% more likely to consume organic tomatoes, but gender differences are not significant for conventional and IPM. Age has a significant negative influence on organic consumption choice but the effect is small. The usual price paid for tomatoes has no significant influence on any of the choices. Frequent consumption of organic products has, however, a significant impact on choices in the experiment. Consuming more than half of organic tomatoes in the real life reduces the probability of consuming conventional tomatoes by 25 percentage points, and increases the probability of consuming IPM tomatoes by 36 percentage points. Surprisingly, real-life organic consumption reduces the probability of consuming organic tomatoes in the experiment by 11 percentage points, suggesting that some organic consumers are switching to IPM in the experiment.

Concerning the impact of prices, we observe that increasing the price of conventional tomatoes by 1 Euro decreases conventional tomato consumption choice by 23 percentage points, and correspondingly increases by 10 and 13 percentage points respectively the consumption of IPM and organic tomatoes. Interestingly, reducing the price of IPM by 1 Euro significantly increased consumption of IPM (52 percentage points), mostly at the expense of organic consumption which decreased by 42 percentage points, while conventional tomatoes consumption decreased only by 10 percentage points. Symmetrically, increasing the price of organic tomatoes by 1 euro benefits mostly to IPM (consumption of organic reduces by 54 percentage points, while IPM consumption increases by 41 percentage points and conventional by only 13 percentage points).

A similar pattern is observed for the impact of shelf space dedicated to each type of tomatoes. Our results indicated that increasing shelf space dedicated to IPM by 10 percent would lead to a 17 percentage points increase in IPM consumption, and significantly reduce conventional tomatoes consumption by 3, and organic by 14, percentage points, respectively. Similarly, a 10 percent reduction in the shelf space for conventional tomatoes reduced conventional consumption by 7.9 percentage points, whilst significantly increasing IPM and organic consumption by 3.5 percentage points and 4.4 percentage points, respectively.

We also observed a significant positive impact of information on consumption. Consumers informed on a production system are significantly more likely to buy the tomatoes corresponding to this production system and less likely to consume other tomatoes. Overall, information had a larger impact for IPM and organic than conventional tomatoes. One could have expected a negative impact of being informed on conventional production on the probability to choose conventional tomatoes, but we did not observe such an impact. The impact of the information on the final characteristics of the product, in terms of residue levels, was lower and significant only at the 10% level. Everything else equal, being informed on IPM increased the probability to choose IPM tomatoes by 17.5 percentage points, but mostly at the expense of organic tomatoes since conventional consumption reduces less than organic consumption (respectively 3.5 and 14 percentage points). Symmetrically, being informed on organic increased the probability to choose organic tomatoes by 18 percentage points, but mostly at the expense of IPM tomatoes since conventional consumption reduced less than organic consumption (respectively 4.5 and 14.2 percentage points).

Table 3: Alternative-specific multinomial probit – estimates

	dp/dx	Robust Std. Err.	P>z
Alternative-specific variables			
Price	-0.8649	0.2169	0.000
Shelf-space	0.2939	0.0029	0.000
Info production	0.3049	0.1315	0.020
Extra information	0.1814	0.1065	0.088
Conventional			
Female	-0.0626	0.2009	0.755
Age	-0.0019	0.0067	0.771
Week_Kg	-0.2699	0.0633	0.670
Usual_price	-0.2311	0.1487	0.120
Half_organic	-1.2769	0.2381	0.000
constant	-1.2689	0.4455	0.004
IPM (base alternative)			
Organic			
Female	0.1267	0.0817	0.121
Age	-0.0047	0.0023	0.043
Week_kg	0.0400	0.0247	0.105
Usual_price	-0.0549	0.0499	0.272
Half_organic	-0.4244	0.1439	0.003
constant	-0.0688	0.1329	0.605
/lnl2_2	-0.7230	0.2625	0.006
/l2_1	0.1638	0.0968	0.090

Note:
Week_Kg: Weekly consumption of tomatoes in november;
Usual_price=Usual Price paid for tomatoes;
Half_organic= More than half of tomatoes consumption is organic

Differenced covariance estimates
(Rk: covariances are for the alternatives differenced with IPM)

	Conventional	Organic
Conventional	2	
Organic	0.2317	0.2923

Table 4: Alternative-specific multinomial probit –marginal effects at means

	Pr (choice = conventional) = 0.33			Pr (choice = IPM) = 0.33			Pr (choice = organic) = 0.34		
	dp/dx	Std. Err.	P>z	dp/dx	Std. Err.	P>z	dp/dx	Std. Err.	P>z
Alternative-specific variables									
Price									
Conventional	-0.231	0.063	0.000	0.102	0.027	0.000	0.129	0.039	0.001
IPM	0.102	0.027	0.000	-0.519	0.064	0.000	0.417	0.064	0.000
Organic	0.129	0.039	0.001	0.417	0.064	0.000	-0.545	0.066	0.000
Shelf-space									
Conventional	0.008	0.001	0.000	-0.003	0.000	0.000	-0.004	0.001	0.000
IPM	-0.003	0.000	0.000	0.018	0.005	0.000	-0.014	0.005	0.004
Organic	-0.004	0.001	0.000	-0.014	0.005	0.004	0.019	0.005	0.000
Info production									
Conventional	0.080	0.033	0.017	-0.035	0.016	0.029	-0.045	0.018	0.016
IPM	-0.033	0.016	0.037	0.175	0.046	0.000	-0.142	0.049	0.003
Organic	-0.040	0.017	0.019	-0.140	0.045	0.002	0.180	0.048	0.000
Extra info									
Conventional	0.049	0.028	0.086	-0.022	0.013	0.108	-0.027	0.015	0.079
IPM	-0.021	0.013	0.105	0.108	0.061	0.078	-0.087	0.054	0.108
Organic	-0.027	0.015	0.076	-0.087	0.054	0.107	0.114	0.064	0.077
Case-specific variables									
Female	-0.035	0.050	0.482	-0.052	0.052	0.318	0.088	0.042	0.035
Age	0.000	0.002	0.915	0.002	0.002	0.118	-0.003	0.001	0.045
Week_Kg	-0.013	0.016	0.400	-0.016	0.015	0.285	0.029	0.013	0.025
Usual_price	-0.053	0.037	0.148	0.054	0.035	0.123	0.000	0.027	0.994
Half_organic	-0.251	0.047	0.000	0.365	0.074	0.000	-0.114	0.055	0.039

Note:

Week_kg: Weekly consumption of tomatoes in november;

Usual_price=Usual Price paid for tomatoes;

Half_organic= More than half of tomatoes consumption is organic

Discussion

We observed that consumers' preferences for IPM tomatoes are strongly impacted by the price difference with organic counterparts. The market share of IPM drops when the price difference between IPM and organic is reduced. Moreover, when conventional tomatoes are withdrawn from shelves, we observe that IPM wins market shares only if the price difference with organic tomatoes is sufficiently high (at least 60 cents per kg). Results of the multivariate probit also suggest that if prices of conventional tomatoes increase (for example due to a tax on chemical input use), conventional tomatoes consumption will decrease, but it will benefit slightly more to organic than IPM consumption. Only a significant reduction in the price of IPM tomatoes compared to organic ones can foster IPM consumption. Moreover, we observed that increasing the shelf space dedicated to IPM leads to an increase in IPM consumption, mostly at the expense of organic tomatoes. The substitutability of IPM and organic tomatoes was also visible through the impact of information since being informed on IPM increased the probability to choose IPM tomatoes, mostly at the expense of organic tomatoes, and vice-versa.

Taken together, the above results indicate that strong substitution opportunities exist between IPM and organic tomatoes, while substitution with conventional tomatoes is more limited. This somehow contrasts results of previous research which showed that IPM was perceived by consumers as a third way, but closer to conventional than organic. Marette et al. (2012) found that the average WTP for apples with a "few pesticides" label was closer to the WTP for conventional apples than the WTP for organic apples. Bazoche et al. (2013) found that, compared with the regular product, the average premium for IPM certification is 24.5 per cent, while it is equal to 50.5 per cent for organic certification.

Given the low knowledge and recognition of IPM in the general public, understanding how to communicate about IPM to the end-consumers appears to be a crucial element to make sure IPM will be seen as profitable by producers. We observed in our experiment that consumers are more interested in information on IPM than on conventional and organic farming. They show interest in both the information on the production system and the characteristics of the final product. We have found that consumers increase their consumption of IPM products when they get access to information on this production system. This suggests that retailers could start communicating to the end-consumer on IPM, rather than limiting IPM as a market-access tool.

However, while residues control is a rapidly growing component of private standards and supermarket communication to consumers, we observed that providing extra information on the residue levels to consumers, in addition to the information on the production system, does not further influence consumers' choices. This suggests that for those consumers not reacting to the information on the production systems, extra information on residue levels does not modify neither their purchase habits. It confirms that only some individuals are responsive to information campaigns and changing the content of the information does not allow reaching other population segments. A further interpretation could be that consumers are not yet ready for messages highlighting the complex and uncertain links between actions (pesticide use) and results (pesticide residues in food). We know from the scientific literature that some of the applied pesticides find their way as residue in food, but their residual quantity differs according to the type of pesticides, the type of products and the production system (Bakery et al. 2002). In the coming years, it will be interesting to confront these results with the analysis of retailers marketing and communication strategies on IPM, in particular with reaction to the new EU legislation.

Another important result concerns the non-significant impact of informing consumers that their consumption choices today impact future prices of IPM and organic tomatoes. It suggests that the option to educate consumers on the impact of their consumption choices on future prices is not efficient. One explanation could be that participants' incentives to contribute to price reduction are reduced in an inter-temporal setting like the one of this experiment (where only the participants of future sessions benefit from the price reduction). We know that inter-temporal settings create anonymity of contributions, and previous research has shown that anonymity reduces voluntary contributions to a public good (Andreoni and Petrie 2004; Rege and Telle 2004; Alpizar et al. 2008). Moreover, while other researchers have found that the inter-temporal setting can favour the idealistic/non-purely economic motives, and therefore the contribution to the public good (Grolleau et al. 2013), such drivers may be difficult to activate here given that the benefits are a reduction in prices, i.e. something very associated to economic motives.

Last, but not least, with the multivariate probit model, we found a strong correlation between consumers' choices of tomatoes and tomato attributes such as price, dedicated shelf space, and availability of information. However, the characteristics of the consumers appear far less relevant to explain choices in the experiment. One may argue that individual characteristics are not significant because there is high heterogeneity in the sample. Accounting for this heterogeneity could provide further insights.

Conclusion

This paper has analysed consumers' choices between Integrated Pest Management, conventional and organic tomatoes. We have conducted a laboratory experiment with 189 French consumers, selected from a sample of ordinary food shoppers. In each of the ten rounds of the experiment, participants could choose to buy fresh tomatoes, indicating the type of tomatoes (conventional, IPM or organic) and quantity they wanted. The experiment was designed to analyse how IPM consumption would be influenced by a reduced availability of conventional products and an increase in the shelf space dedicated to IPM products following the change in the European legislation on crop protection. Furthermore, we also studied the impact of providing extra-information to the consumers on the pesticide residues in tomatoes, in addition to the information on the different production systems and crop protection strategies.

Results indicate the existence of strong substitution opportunities between IPM and organic tomatoes, whilst substitution with conventional tomatoes appears more limited. Experimental results also indicate that the withdrawal of conventional tomatoes from shelves due to the implementation of the Sustainable Use of pesticides Directive could benefit organic rather than IPM sales if the price difference between organic and IPM is low, even if organic produces are more expensive. Only a significant reduction in the price of IPM tomatoes, compared to organic and/or an important increase in the shelf space dedicated to IPM, would appear to increase IPM sales. However, raising awareness on the impact of consumption choices on future prices of the product has only a limited impact in this context. Results also provided an insight into the nature and extent of information for communication to consumers to increase their understanding of IPM. While information on IPM guidelines increases IPM products purchases, providing extra information on residue levels in IPM tomatoes has no further impact on consumers' choices.

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Annex A: Information available to participants upon request (translated from French by the authors)

More information on the production system (available only from round 2)	Generic information on production system (displayed for Conventional, IPM and Organic)	Crop protection has a key role in agriculture since it protects crops from weeds, diseases and pest which are major causes of yield losses. Many crop protection methods exist (chemical pesticides, choice of crop varieties, soil management, use of beneficial insects...) and are used according to the crop protection strategy chosen by the farmer.
	Conventional	In conventional farming, chemical pesticides are used systematically and routinely for crop protection. It is the kind of crop protection which dominated the 20th century and which accounts for most farming today. Tomatoes from conventional farming receive on average 30-35 spraying during the growing season (average for soil-less tomatoes, which represent most of tomatoes production in conventional agriculture)
	IPM	Integrated Pest Management can be considered as a third-way between conventional and organic crop protection strategies: the use of chemical pesticides is not prohibited but limited, thanks to a more efficient and targeted spraying and to the use of other methods (physical protection, organic protection, cultural practices ...). Many tomatoes are produced nowadays with integrated pest management but the information is rarely disclosed in supermarkets. Spraying of tomatoes is reduced to less than 5 per growing season with integrated pest management. This is less than in conventional farming but more than in organic (average for soil-less tomatoes, which represent a large majority of the tomatoes produced with integrated pest management).
	Organic	The specifications for organic farming totally prohibit the use of chemical pesticides. All organic tomatoes are soil- grown and with no chemical pesticides, contrarily to crop protection

		strategies used in conventional farming and integrated pest management.
More information on the characteristics of the final product (available from round 5)	Generic information on pesticide residues (displayed for Conventional, IPM and Organic)	Pesticides tend to stay in fruits and vegetables, even after washing or peeling them. In order to protect consumers' health and promote good practices in farming, maximum residue levels have been set legally. It aims at avoiding that consumers eat more than the acceptable daily intake of the active substance. Fruits and vegetables with residue levels beyond this limit cannot be sold.
	Conventional	All conventional tomatoes contain less pesticide residues than the maximal limit imposed by regulation.
	IPM	Tomatoes produced according to Integrated Pest Management contain less pesticide residues than the maximal limit imposed by regulation, and, in average, 10 times less pesticides residues than what is observed in tomatoes from conventional production system.
	Organic	Chemical pesticides not being authorized in organic farming, organic tomatoes can be considered as residue-free compare to conventional and IPM tomatoes. However, some studies have revealed that residues can be found in organic tomatoes, since pesticides can have been used in neighbour fields or in the past in the same field.

Annex B: Messages justifying the changes in the shelf space dedicated to IPM (translated from French by the authors)

Disclosed to all participants between rounds 6 and 7	The European Union has decided that from 2014, all farmers will have to use Integrated Pest Management to protect their crops against pests and diseases. Crop protection strategy as currently used in conventional production system will therefore be prohibited from 2014. Since farmers are anticipating this change, we can already observe that the share of conventional tomatoes in total production is diminishing. There is now only one type of conventional tomatoes available, plus on type of IPM and one type of organic tomatoes.
Disclosed to all participants between rounds 8 and 9	Crop protection strategies used in conventional production system will be forbidden starting from 2014. From now, only IPM and organic tomatoes are available.

Annex C: Tomatoes prices

€/kg		Conventional (round)	Conventional (Large Tomatoes-On-Vine A)	Conventional (Large Tomatoes-On-Vine B)	IPM	Organic	Price difference (Organic-IPM)
Summer (sessions 4,5,9,10)	Reference (rounds 1 and 2)	1.5	1.9	2	2.2	2.6	0.4
	Price list 2 (rounds 3, 5, 7 and 9)	1.1	1.7	1.8	2.4	3	0.6
	Price list 3 (rounds 4, 6, 8 and 10)	1.5	1.6	1.7	2.5	2.6	0.1
Autumn (sessions 1,2,3,6,7,8)	Reference (rounds 1 and 2)	1.5	2	2.2	2.5	3	0.5
	Price list 2 (rounds 3, 5, 7 and 9)	1.1	1.8	2	2.7	3.4	0.7
	Price list 3 (rounds 4, 6, 8 and 10)	1.5	1.6	1.7	2.5	2.6	0.1