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Report on socio-economic driving forces of different plant protection strategies in pomefruit production in four EU-regions

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Table of Contents

Glossary

Acceptable Daily Intake: amount of a substance in food that can be ingested daily over a lifetime without appreciable health risk to the consumer. It reflects the chronic or long-term toxicity.

Acute Reference Dose: amount of a substance in food that can be ingested over a short period of time without appreciable health risk to the consumer. It represents the acute or short-term toxicity.

Harvesting interval: number of days between the application day and the harvesting day.

Integrated Control: the rational application of a combination of biological, biotechnological, chemical, cultural or plant-breeding measures whereby the use of chemical plant protection products is limited to the strict minimum necessary to maintain the pest population at levels below those causing economically unacceptable damage or loss (EU, Dir 411/91).

Integrated Pest Management: the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep plant protection products and other interventions to levels that are economically justified and reduce or minimise risks to human health and the environment. Integrated Pest Management emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural and non-chemical pest control mechanisms (GlobalGAP).

Maximum Pesticide Residue Levels: the highest levels of pesticide residues that are legally tolerated in food and expressed in mg/kg applies. The European Commission fixes them. The European Food Safety Authority make the estimations to guarantee that the residue levels in food are safe for consumers and as low as possible, based on scientific information about the toxicity of the pesticide, the amount of pesticide necessary to protect the crop, the expected level remaining in food and patterns of consume and diets.[1]

Main apple diseases: apple scab (*Venturia inequalis*), fire blight (*Erwinia amylovora*), European canker (*Nectria galligena*), powdery mildew (*Podosphera leucotricha*).

Main apple pests: codling moth (*Cydia pomonella*), rosy aphid (*Disaphis plantaginea*), fruit tree red spider mite (*Panonychus ulmi*), Mediterranean fruit fly (C*eratitis capitata*).

[1] http://ec.europa.eu/dgs/health_consumer/press/pesticide_residues.pdf

Summary

The objective of this study is to produce realistic recommendations to implement farming systems that are less reliant on pesticides. Therefore, socio-economic driving forces that affect crop protection strategies are identified and explained in a dynamic context.

This research was conducted in four regions, each of them standing for a particular plant protection strategy. These strategies are defined according to two attributes of pesticide use, the quantity applied and the characteristics and intrinsic properties of their active ingredients. Four apple-growing regions were selected from a classification of agricultural systems implemented in the production of fruit trees in European countries. The regions are: Lerida in Spain, Kent the United Kingdom, Lake Constance in Germany and Emilia-Romagna in Italy.

Data, which was collected by means of semi-structured interviews with different stakeholders who may influence pesticide use decisions and complemented with statistics and scientific information was analysed under a qualitative approach.

In order to understand pesticide use decisions, the motivational and knowledge systems were described, socio-economic driving-forces that influence pesticide use choices identified and conclusions drawn for implications regarding the two pesticide use dimensions.

It was found that the motivational aspects are guided by economic (i.e. profitability) and food safety (e.g. zero pesticide residues in apples) aims. The key factor to satisfy both objectives is the market access, specifically through supermarkets, which account for the largest share of apple trade. It implies that pesticides are applied in a quantity that represents a low crop loss risk, while the type of products applied is defined by commercial established standards, which are enforced through private schemes of certification of so-called good agricultural practices.

It was recognised that the knowledge about crop protection issues (e.g. set of pest thresholds, disease modelling) according to the particular conditions of the regions is well developed; common tendencies in the use of the decision support system, the scope of the advisory services as well as in actions to enhance the capability of fruit growers (i.e. training) and improve the efficiency of the applications (e.g. calibration and maintenance of application equipment) are supported by cross compliance policies and private certification schemes; and in the information given to fruit growers in form of tactical strategies, priority is given to accomplish safety standards over use of all technical available resources (e.g. few disease resistant varieties are grown, authorised active substances are restricted, partial maximum residue levels are demanded). It implies that pesticides are applied in quantities required to control pest and prevent diseases, which depend on the climatic conditions, while the selection of the type of products follows the requirements of commercially established standards and is adapted to the availability of products (e.g. the number of insecticides and fungicides registered have been reduced in the last 10 years, the registration of biocides is not homologated among countries).

Challenging for policy-makers is that the concept of integrated pest control is defined and adapted to specific crop and geomorphologic conditions. The new Framework Directive on Sustainable Use of Pesticides COM 373/2006 promotes the adoption of general standards, but substituting commercially oriented standards with technical based ones implies increments in public investment in control.

Definitions

ADV – Asociacion de Defensa Vegetal (Plant protection group)
AGROS – Agroscope Reckenholz-Tänikon Research Station ART (ENDURE Member)
AP – Assured Produced certification scheme
AS – Active Substances / Active Ingredients
BRC – British Retail Consortium
CAPRI – Common Agricultural Policy Regional Impact Analysis Model of the University of Bonn
EC – European Commission
ENDURE – European Network for Durable Exploitation of Crop Protection Strategies
EMR – East Malling Research
ER-IT – Emilia-Romagna, Italy
EU – European Union
FDSUP – new EU Framework Directive on Sustainable Use of Pesticides
GAP – Good Agricultural Practices
HDC – Horticultural Development Company
IFS – International Food Standards
IP – Integrated Production
JKI – Julius Kühn-Institute (ENDURE Member)
K-UK – Kent, United Kingdom
KOB – Kompetenzzentrum Obstbau-Bodensee
L-ES – Lerida, Spain
LC-DE – Lake Constance, Germany
LEAF – Linking Environment and Farming
MRL – Maximum Pesticide Residue Levels
PU – Pesticide Use
SF – Servizio Fitosanitario Regione Emilia-Romagna
SSV – Servicio de Sanidad Vegetal of Catalonia
UdL – Universidad de Lleida (ENDURE Member)
UK – United Kingdom
UNECE – United Nations Economic Commission for Europe

Introduction

Through development and evaluation of new technologies, alternative methods and improved cropping systems, ENDURE's research demonstrates that there is a potential for designing farming systems that are less reliant on pesticides[2]. Complementarily, scientific investigations should be oriented to support the implementation of these innovative farming systems. Therefore, within the Research Activity 3.2 an "Analysis of socio-economic driving forces in crop protection strategies" is conducted. This analysis include: (1) the classification of plant protection strategies currently implemented in Europe based on two attributes of pesticide use - PU, the quantity and the type of pesticides applied (ENDURE Deliverable RA 3.2), (2) the explanation of the different strategies by understanding PU decisions (this ENDURE Deliverable) and (3) the elaboration of policy recommendations.

Towards understanding PU decisions, socio-economic factors that affect crop protection strategies are not only identified, but also explained in a dynamic context. Accordingly, the analytical procedure utilised to produce this Deliverable gathers on: (1) the description of the motivational and knowledge systems related to PU decisions, (2) the identification of socio-economic driving forces that influence pesticide use choices and (3) the deduction of implications for the two PU attributes. The results of this analysis are useful for making recommendations that favour the implementation of the new EU Framework Directive on Sustainable Use of Pesticides – FDSUP (Com 373/2006/EC).

1. Material and Methods

1.1. Theoretical background

To answer the research questions "which socio-economic factors affect crop protection strategies and how it occurs" it is considered that the two attributes of PU (by which crop protection strategies are defined), the quantity and the type of pesticides result from growers decisions about when a pesticide treatment should be carried out, which pesticide product should be applied and at which dose. From the human behaviour theory, it is understood that rational decision-making requires knowledge and choice between alternatives, and is also influenced by motivations (e.g. altruism, command actions or self-interest) (see Figure 1. Analytical Framework) (Kasper and Streit, 1998). This analysis is conducted under the framework of the institutional economics theory, which focuses on understanding the role of institutions and rules in shaping human behaviour (Ostrom, 1998).

1.2. Data collection and analysis

Data was collected by means of semi-structured interviews with different stakeholders, who may influence PU decisions. When using semi-structured interviews, main topics are outlined and identified ahead, during the interview focus is adjusted according to the implication of the interviewer and additional questions may be arisen to discuss specific issues. These stakeholders are: farmers, public and private advisors, pesticide dealers, and representatives of certification agencies, growers' associations, fruit retailers, public agencies, and agricultural research institutions. The interview included four main topics: (1) who is responsible for PU decisions and which are the motivations to use pesticides, (2) the knowledge and perceptions about PU and other factors that may affect PU decisions, (3) PU innovation and the selection of pesticide products and (4) PU intensity and other farm management strategies. Complementarily, information was extracted from statistical

[2] In: Action needed to speed IPM development (January 22, 2009), www.endure-network.eu

databases, reports, documents (e.g. regional guidelines for integrated fruit production) and scientific papers.

For the data analysis, a qualitative research approach, which concentrates on the study of social life in natural settings (Punch, 2005) was applied; more specifically, the content analysis method. It implies that categories (concepts) were brought to the empirical material, but continuously assessed against the data and modified when necessary (Mayring, 2004). Techniques such as summarizing were implemented to achieve the objective of generalising the material on a higher level of abstraction (Flick, 2006). In order to draw conclusions, similar patterns and structures were identified and set as a base line and then, comparisons among features of the four different regions were made.

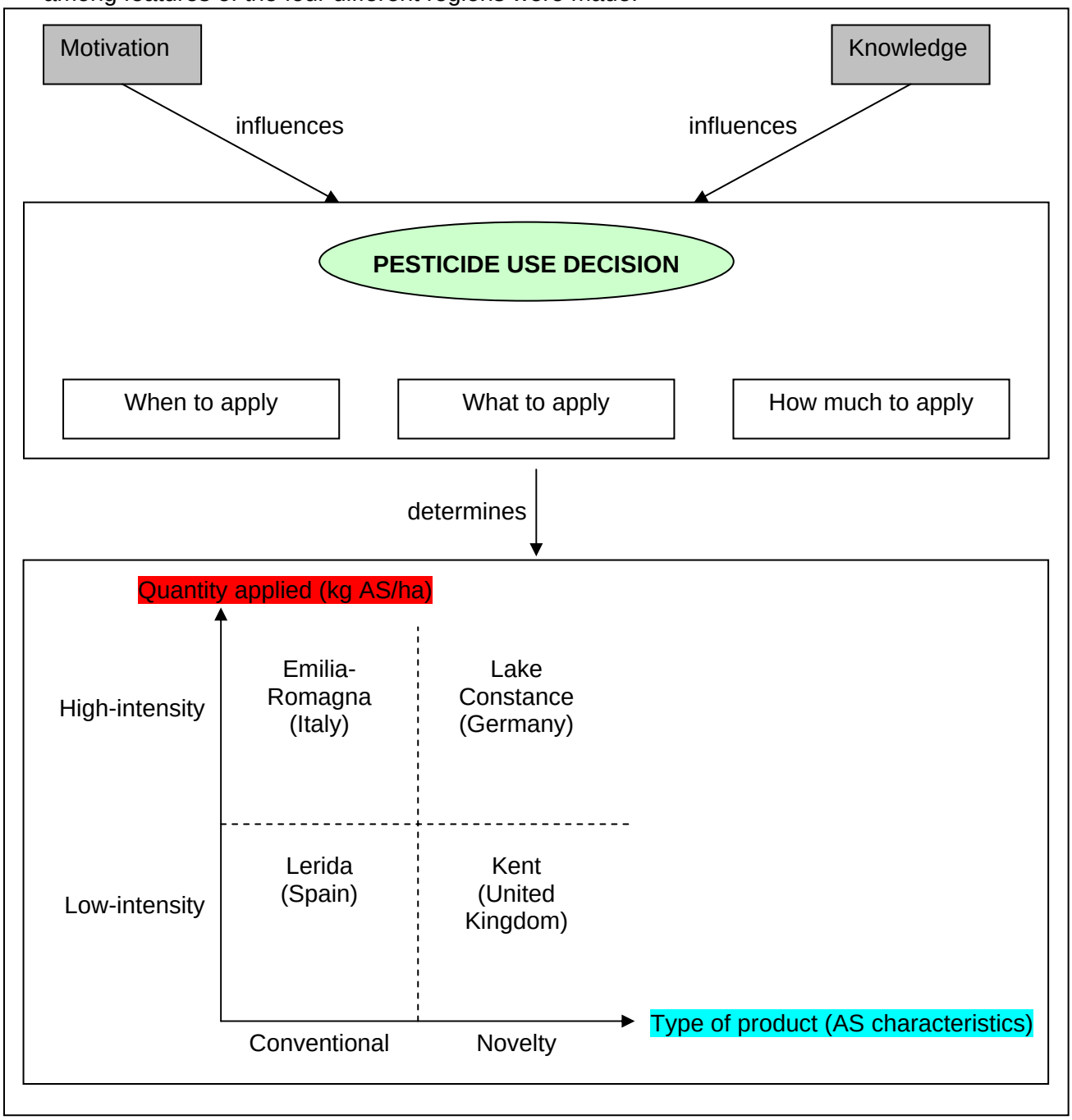

Figure1. Analytical Framework

1.3. Regions and partners

The research was conducted in four apple growing regions, each of them representing a particular plant protection strategy. The different strategies were defined according to two attributes of PU, the quantity of active ingredients (substances) - AS applied per hectare (between 2000 and 2003) and the characteristics and intrinsic properties (e.g. toxicity for humans, potential risk for groundwater, side-effects on beneficial organisms, etc.) of those AS. These PU attributes were calculated for the production of fruit trees in different European countries, which demands a large proportion of the pesticides applied in the European Union – EU (Eurostats, 2007). Each PU attribute was divided in two levels (see ENDURE Deliverable RA3.2).

In this analysis, the regions characterised by high-intensity of PU are **Lake Constance in Germany – LC-DE**, where AS with novelty inherent properties (e.g. lower toxicity) were applied and **Emilia-Romagna in Italy – ER-IT**, where AS with conventional inherent properties were applied. While, **Kent in the United Kingdom – K-UK**, where AS with novelty inherent properties were applied and **Lerida in Spain – L-ES**, where AS with conventional inherent properties were applied stand for low-intensity of PU in apple production.

The Interviews were conducted by José Hernández (AGROS) and coordinated by Jesús Avilla (UdL) and Joan Solé (UdL) in **Lerida**, Volkmar Gutsche (JKI) and Christian Scheer (Kompetenzzentrum Obstbau-Bodensee – KOB, an external partner) in **Lake Constance**, Riccardo Bugiani (Servizio Fitosanitario Regione Emilia-Romagna – SF, an external partner) in **Bologna, Emilia-Romagna**, and Jerry Cross (East Malling Research – EMR, an external partner) in **East Malling, Kent**. Within the coordination tasks, ENDURE and external partners were responsible for contacting the different stakeholders with whom the interviews were made, set an agenda and support logistically the performance of the interview.

2. Motivational system

2.1. Description and elements of the system

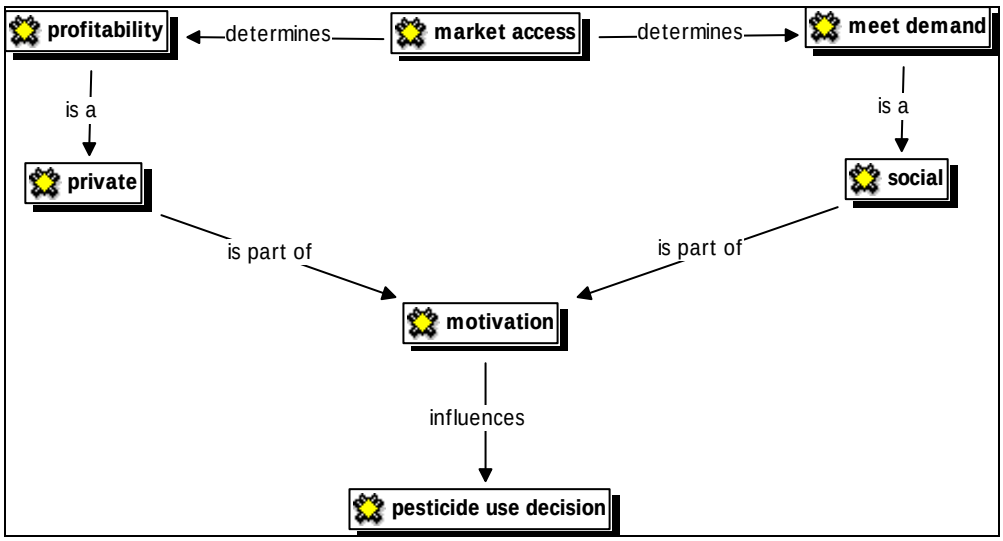

Figure 2. Motivational system of pesticide use decisions

The use of pesticides in the apple production contributes to achieve two objectives of this economic activity, a ***private*** one that concerns with earning ones' living (i.e. profitability) and a ***social*** one related to providing food (e.g. meeting fruit demands). The motivational system of pesticide use decisions is shown in the Figure 2.

2.1.1. Private motivation

The profitability of the apple production may be calculated as the difference between the revenues and the costs of the production, where the revenues are equal to the product of the crop yield and the fruit price. Another factor that should be taken into account is the quality of the fruit, which finally determines both the price paid to growers and the access to the market.

2.1.2. Social motivation

To meet the demand for fruits, the growers should not only attain specific quantities, but they should also produce apples with particular physical conditions (i.e. size, taste, appearance) and food values (i.e. pesticide residues, traceability). The access to the apple market is also restricted by a certification to the agricultural practices implemented in fruit production.

2.2. Socio-economic factors that affect plant protection strategies

2.2.1. By influencing crop yields obtained

The quantity of fruit that is produced depends among others on the variety that is planted. The core factor in the *selection of the varieties* is that what is demanded on the market for rather than what is easier to grow. Thus, the majority of the apple varieties that are currently harvested in the four regions (Golden Delicious in **L-ES**, Fuji in **ER-IT**, Gala in **K-UK** and Jonagold in **LC-DE**) are characterised for being highly susceptible to *Venturia inequalis*, a key disease in the apple production in Europe.

The *intensification of the agricultural production*, not only implies higher demand of inputs such as pesticides, but also corresponds to higher levels of production. In the regions under study, the average yields obtained in apple production with high-intensity of PU (35.7 t/ha in **LC-DE**, 28.9 t/ha in **ER-IT**) are greater than those obtained with low-intensity of PU (24.9 t/ha in **K-UK**, 26.8 t/ha in **L-ES**).

2.2.2. By influencing crop production costs

The *costs of PU within the crop production expenditures* represent in the case of fruit production a relative small percentage that ranks between 7% and 16% (7.1% in **ER-IT**, 10.4% in **LC-DE**, 16.2% in **L-ES**, 16.6% in **K-UK**)[3]. That these costs are lower for production systems characterised by high-intensity in PU might be related to the higher costs of non-chemical alternatives of pest control (when compared with conventional pesticides) and the increase of farm operations (e.g. monitoring, mechanical weeding) and consequently higher labour costs in farming systems characterised by low-intensity in PU.

In addition, it is important to note that reductions in PU may be considered as a risky attitude. Pesticides are used to avoid crop losses and have been proved to be efficient when controlling pests and diseases, while non-chemical alternatives in control of pests may have lower effectiveness, are normally more expensive (than conventional pesticides) and do not work on their own (pesticides still needed).

[3] Percentages calculated for apple-pear-peach production between 2001 and 2003. Data taken from the CAPRI-Model of University of Bonn

2.2.3. By influencing fruit prices

Only one *premium price* compensates directly the production process and is paid for organic apples. However, the percentages of organic apple production in terms of area in the four regions under study are very low (3% in **LC-DE**, 2,5% in **ER-IT**, less than 1% in **K-UK** and less than 0.5% in **L-ES**). In the two growing areas characterised by application of novelty AS (**LC-DE** and **K-UK**), the certified production that follow a "regional defined" integrated production – IP scheme (i.e. Qualitätszeichen Baden-Württemberg and Assured Produce Scheme) is taken as the standard farming system. While, in the other two growing areas (**L-ES** and **ER-IT**) the certification with "regional defined" IP schemes (i.e. Norma Tècnica per a la Producció Integrada and Disciplinari di Produzione Integrata) is equivalent to an extra cost that is not compensated in the fruit prices.

The appearance of the fruit and the allowed defects determine the *market value of apples*. In some cases, *premium prices* are related to specific apple varieties, for example, when introducing a new variety in the market or promoting regional grown fruits. According to the commercial quality standards of the UNECE[4], fresh apples are classified in: Extra Class, Class I and Class II. An Extra Class apple must be of superior quality with shape, size and colouring characteristic of the variety, intact stalk, and flesh do not affected by rotting or deterioration and free from defects excepting very slight superficial defects that do not affect the general appearance of the fruit. In the Class I, apples must be of good quality and slight defects in shape, development, colouring, skin (with special condition given to scab) may be allowed on individual fruit. In the Class II, apples that do not qualify for being considered as Extra Class or Class I are included, in the case that these apples are clean or practically free of any visible foreign matter, practically free from pests, free from damage caused by pests affecting the flesh, free of abnormal external moisture, and free of any foreign smell or taste, some defects in shape, development, colouring, and skin are allowed.

2.2.4. By meeting the demand for fresh apples

In addition to the prices, consumers pay also attention to the *appearance* (e.g. colour, striking name) and the *eating qualities* (e.g. taste, firmness, juice content) of the fruit. However, it is unclear how the consumers set a balance among these factors.

In the case of the attractiveness, bi-coloured varieties (striped) seem to be preferred nowadays. For example, in **England**[5], The bi-coloured segment of the English market of apples accounts today for more than the half of the market share (Gala and Braeburn represent about 40% of the market share and Pink Lady, Fuji, Jazz, Rubens are also produced). While, greenish varieties such as Granny Smith and yellowish varieties such as Golden Delicious, which accounted for about 50% of the English apple market back in the 1990's, cover today only about 25% of the market. Block red varieties such as McIntosh and Red Delicious are less consumed and apparently are associated to not having a good taste and to being of soft texture.

The production (and consequently the consumption) of apples is linked to the weather conditions, for example, in **L-ES**, the most grown apple is the yellowish variety Golden Delicious, in this region obtaining a red coloration on the apples is not a viable task due to the solar radiation conditions (i.e. hours of exposure per day and extremely high temperatures).

The pattern of consumption, when considering eating qualities and attractiveness, is difficult to be typified. For instances, **English** consumers are thought to be looking for apples with

[4] United Nations Economic Commission for Europe – Agricultural Standards Unit of the Trade and Timber Division

[5] from a recount made by a representative of an association of English growers of apples

good texture (crisp and crunchy), juice content, complex taste (good sugar acid balance) and that look attractive (stripes and striking name). Thus, it could be expected that a variety such as Pink Lady would be the most demanded. However, the consume of Gala, which is characterised by having a more intensive yellow colour in the background that is associated with over mature fruits and a very straight forward sweet flavour is nowadays higher.

Excess on the *maximum pesticide residues levels* – MRL imply that the fruits cannot be commercialised. The MRL have been harmonised in the EU by means of the Regulation EC no.394/2005 (which came into force in September 2008). Officially, national programmes to control residues and specific rules on sanctions applicable to infringement are established (in accordance with the Regulation EC no. 882/2004). The official controls on pesticide residues consist of sampling at the point of supply to the consumer and identifying the pesticides present and their respective residue level. The results of these monitoring programmes are due to be published annually.

The monitoring plans are coordinated at national level and carried out by regional authorities (i.e. Federal Laender in **Germany**, Autonomous Communities in **Spain** and Autonomous Regions/Provinces in **Italy**), except in the **United Kingdom – UK** . The national authorities for pesticide residue monitoring are: the **German** Federal Ministry of Food, Agriculture and Consumer Protection, the Pesticide Safety Directorate in the **UK**, the General Directorate for Food Safety and Nutrition of the **Italian** Ministry of Health, and the **Spanish** Ministry of Agriculture, Fishery and Food and the **Spanish** Nutrition and Food Safety Agency.

Fruit retailers (supermarkets), marketing organisations and growers' associations also conduct tests of pesticide residues in fruit. Excess in MRL imply that the produce is immobilised. Some supermarkets, which are the most significant channel for retail of fresh apples (e.g. in **Germany** they put on the market 70% of apples produced in **LC-DE**, in the **UK** they account for 84% of the total sales of apples) established stricter limitations to pesticide residues on fruits[6]. These tighter limitations to pesticide residues include, lower residue levels than those allowed by law (between 33 and 80%), restrictions to the number of different active substances detected on fruits (between 3 and 5), non excess of a percentage (between 70 and 80%) of the Acute Reference Dose, non excess of the Acceptable Daily Intake, and prohibition or restriction (with permission only) for the use of certain products that are included in a black list of pesticides. Some retailers conducting these practices have been identified in the Netherlands, **Germany**, Austria and the **UK**.

The production of residue-free apples has been challenged by different stakeholders, and even a zero residue integrated pest and disease management programme for apple has been developed in the **UK**. In this programme of production, the application of synthetically derived chemicals was avoided during the fruit development period (Cross and Berry, 2008). Successfully strategies to reduce the incidence of pesticides and thereby the level of residues present on the fruit include: growing varieties that are resistant to common diseases and pests (which normally are not known in the market), implementing non-chemical methods (cultural and biological) of control, establishing the needs of pesticide use through pest monitoring and disease risk forecasting, applying pesticides more intensively earlier or later in the season (pre-flowering or post fruiting), using pesticides with shorter persistence and products with high reporting limit relative to their dose, increasing the harvesting interval.

In the case of apple production in **L-ES** and **ER-IT**, the limitations in terms of allowed pesticide residue levels are higher when the fruit is intended to be exported to countries where stricter restrictions are on operation (e.g. China). Furthermore, controls to this specific trade barrier may be even out of the scope of the World Trade Organisation (e.g. Russia).

[6] according to information published by the Pesticide Action Network Europe http://www.pan-europe.info/Resources/Factsheets/Supermarkets.pdf

The *certification of good agricultural practices* – GAP becomes in other condition required for the commercialisation of fresh apples through the supermarkets. The most widespread standard is called "GlobalGAP", a scheme that was set up by the Euro-Retailer Produce Working Group and is aimed to guarantee the safety of the produces and the implementation of environmentally friendly practices in the agricultural production. The performance of these "GAP" in agricultural production is thought to have positive effects on food security, worker health and safety, and environmental and animal welfare.

The GlobalGAP certification is not equivalent to the guidelines established for regional certifications of IP (Gesicherte Qualität Baden-Württemberg, Qualità Controllata – Legge Regionale dell´Emilia-Romagna, Producció Integrada Catalunya). Only in the case of the Assured Produce certification scheme – AP it is equivalent, as its general regulations and control points have been benchmarked against the GlobalGAP scheme[7]. Thus, apple producers in **K-UK** are able to ask for a certificate confirming the equivalence.

The GlobalGAP certification is voluntary and covers different levels of the agricultural production (i.e. all farm, crop base, specific crops / e.g. fruit and vegetables). The certification process is based on audits of specific control points according to compliance criteria, which are classified as major must (100% should be observed), minor must (at least 95% of the applicable criteria should be fulfilled) or recommendations.

In the crop base standards, three of the control points listed can be related to PU decisions: propagation material, integrated pest management and plant protection products. Under the propagation of material, a minor must is that the producer should be able to demonstrate "awareness" of variety pest and disease resistance when available and justify the selection of the variety. Thus, the selection of pest or disease tolerant apple varieties is not necessarily enforced.

Similarly, in the case of integrated pest management, there are six control points, all of them categorised as minor must compliance criteria. Additionally, the observance of these control points seems to be low-demanding. For instances, the performance of at least one farm activity within the strategies to prevent pests, diseases or weeds is enough for the fulfilment of the compliance criteria.

In the case of plant protection products, and according to the number of compliance criteria categorised as a major must, more importance is given to record of applications (justification of an intervention and detailed documentation), choice of pesticides (use of authorised products for the specific crops and target pest or disease), pesticide residue analysis (awareness of the MRL), storage of pesticides and disposal of empty pesticide containers. Dissimilarly, specific training issues are lacking and the compliance criteria for application equipment and disposal of surplus application mix are categorised as a minor must.

Supermarkets have established in addition other private farming certification schemes. In the **UK**, for example, some of these schemes are, Linking Environment and Farming – LEAF (set by Waitrose), Field to Fork (set by Marks & Spencer) and Natural Choice (set by Tesco). "The LEAF marque is a guarantee to consumers that the producer operates their business and production techniques in an environmentally responsible way"[8]. The Field to Fork assurance scheme, specifically designed to cover fruit and vegetables, focuses on reducing the level of pesticides used by the suppliers, encouraging them to support production which benefits the environment, and generally enhancing the brand through rigorous food safety[9].

[7] http://www.assuredproduce.co.uk/resources/000/308/474/Produceautumn086.pdf
[8] http://www.waitrose.com/food/foodissuesandpolicies/leaf.aspx
[9] http://www.agrifoodstandards.net/en/news/global/m_s_revises_field_to_fork_assurance.html

Tesco asks its suppliers to comply with its Nature's Choice scheme to ensure that fruit, vegetables and salad are produced to high safety, quality and environmental standards"[10].

Besides of being a marketing strategy to differentiate produces, the private certification schemes are more demanding for the growers than GlobalGAP is. In the case of LEAF, some of the Critical Failure Points (equivalent to the Control Points of GlobalGAP) included within the crop protection issue are: implementation of strategies to avoid resistance, training in identification of pest, disease and crop disorders, consideration of environmental impacts of all crop protection practices, actions to minimise damage to beneficial organisms and wildlife, use of pesticides limited to the area that is required, definition of a process to deal with spillages damaging the environment, regular update of operators and managers in the proper use of pesticides.

For the trade of fresh produces within the EU, other certification schemes are required such as the British Retail Consortium – BRC and the International Food Standards – IFS (created by German and French trade organisations). These schemes are also intended to confirm the observance of environmentally sound crop production practices and to ensure the food security of the crop outputs. This rule-in-use affects those apple growers located in exporter countries, in this case in **L-ES** and **ER-IT**.

2.3. Implications for pesticide use

In the Figures 3 and 4, these factors that have been identified from interviews and complementary information as driving forces of PU decisions under the motivational perspective are contained and their linkages are illustrated. These connections are helpful not only to draw conclusions about causal relationships, but also to understand the PU decision-making process in a dynamic context.

The motivational aspects of PU decisions are guided by economic and food safety aims of the agricultural production and the key factor to successfully satisfy both objectives is the access to the market. In the case of fresh apples, the retail through supermarkets corresponds to the largest source of fruits for consumers.

As a conditional requisite for commercialisation of crop produces, supermarkets have developed and implemented private schemes of certification of crop production processes. With these certifications is guaranteed that a commercially defined set of GAP are implemented in fruit production. These GAP are characterised by standards focused on safety of consumers, operators and the environment. A commercial strategies of supermarkets to difference their products is associated with the establishment of more and stricter GAP requirements.

These private schemes of certification are also characterised by only requesting the completion of commercially accepted/adapted versions of technical aspects or farm operations of "IP". Thus, apple varieties that are high susceptible to *Venturia inequalis* are frequently grown (and demanded for). Additionally, in crop protection, priority is given to safety issues (e.g. reduction of residue levels) over labours of prevention, observation and intervention (e.g. use of all legally authorised pesticides).

Apples that are intended to be commercialised through supermarkets should possess special shape, size, coloration and skin attributes.

The economic incentive for the apple production can be satisfied when an adequate quantity of fruit of accepted marketable quality is produced at the lowest costs possible.

[10] http://www.tesco.com/todayattesco/green/archive/0607_03_034_ggn_04.shtml

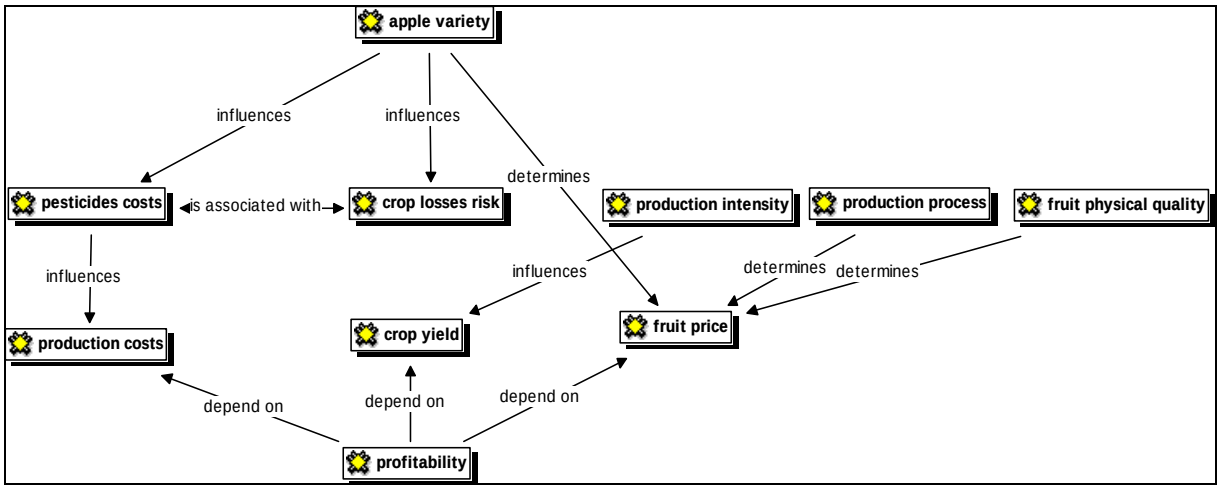

Figure 3. Factors related to the private motivation affecting crop protection choices

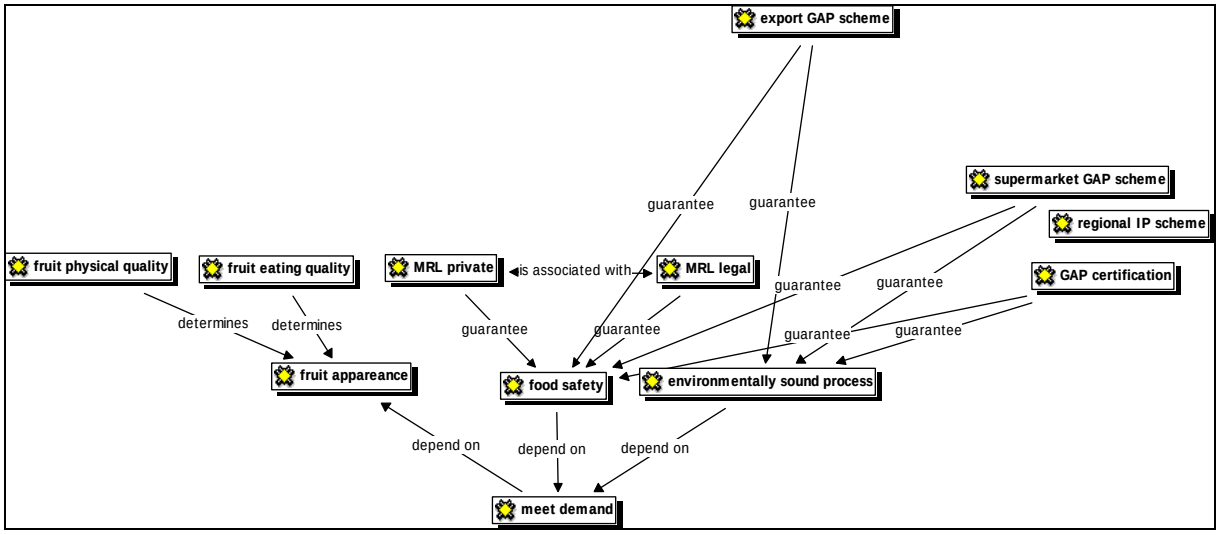

Figure 4. Factors related to the social motivation affecting crop protection choices

2.4. Socio-economic driving forces of pesticide use decisions

2.4.1. When fixing the quantity of pesticides

Independent of the intensity level of PU of the agricultural systems, the use of synthetically derived chemical products in crop protection is a mandatory labour, because disease susceptible varieties are grown. Other aspect that acts to encourage the use of pesticides is their effectiveness in avoiding crop losses and thereby producing higher percentages of commercially demanded fruits.

The implementation of tactic strategies of plant protection that are oriented by the commercially defined concepts of food safety and environmentally responsible crop growing can be found either in a PU high-intensive farming system or in an agricultural production with low-intensity in PU.

A relation between the increase in the intensification of the agricultural production specified by the level of PU (from low to high) and the decrease of the relative costs of pesticide plant protection is noticed.

In conclusion, farmers are likely to use pesticides whenever this tactic constitutes an economically lower risk strategy of plant protection. Quantities of pesticides applied are influenced by the intensity of the production and their costs.

2.4.2. When choosing the type of pesticides

PU practices are shaped by the operation of commercially enforced methods that guarantee low presence of pesticide residues in fruits and a crop production obtained by means of processes that are secure for the humans and the environment. The use of pesticide products characterised by novelty properties coincide with significant implementation of supermarkets' certification schemes and standards.

It is important to note that the previous assertion neither means that no-pesticides are applied at all, nor that the use of pesticides characterised by conventional properties should be catalogued as a bad practice.

In conclusion, the implementation of commercially established standards of crop production certification exerts an influence in the selection of the type of pesticide products that are applied. In this practice completing commercially established fruit production processes has priority over using all the technically available tools of plant protection.

3. Knowledge System

3.1. Description and elements of the system

Growers facing PU decisions rely on information obtained from their **experiences** and perceptions, their **interactions** with other growers, the **recommendations and advices** they get, and their participation in crop protection focused **training** and educational activities. The first two listed sources can be analysed better by means of an on-farm level survey (out of scope in this investigation). Recommendations include technical advices from public funded networks and fruit marketing organisations and commercial advices supplied from pesticide producers' networks. The knowledge that growers and farm workers acquire through training and education is linked to their capability (i.e. skills) and the implementation of practices and techniques that may enhance the efficacy of the applications. The components of the knowledge system affecting crop protection choices are shown in the Figure 5.

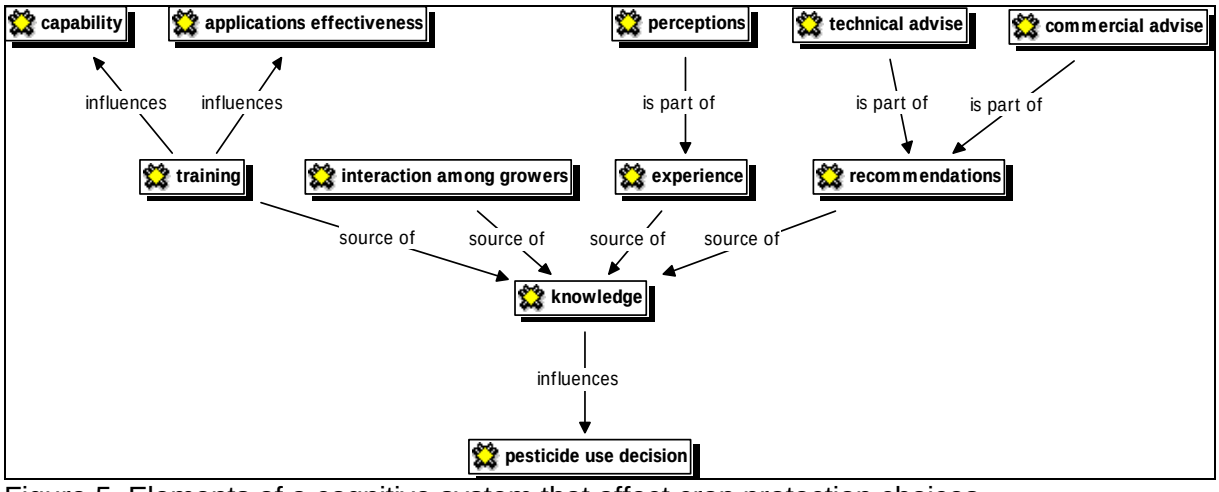

Figure 5. Elements of a cognitive system that affect crop protection choices

3.1.1. Advices and recommendations

3.1.1.1. Information given to fruit growers

Recommendations of treatments with fungicides to prevent diseases are concluded from risk *estimations of potential disease infestations*, which in most of the cases are modelled according to the epidemiology of the disease and in function of the climatic conditions (temperature, moisture and precipitation). The severity of the disease attack may vary according to the vegetative phase of the apple trees and the presence of disease inoculums from the previous growing season (Garcia de Otazo, et al., 1992).

Pesticides applications to control insects are recommended once is verified that the *pest occurrence exceeds a pre-established threshold* (e.g. number of captures of male insects in pheromone traps) and the conditions of temperature and moistures are ideal for the reproduction of that specific insect (Garcia de Otazo, et al., 1992). The thresholds that are used in the four regions for *Cydia pomonella* (the most common pest problem in European apple production) control have been set some years ago and are calculated to guarantee low percentages of crop losses.

When giving a recommendation, the arguments for the selection of the *pesticides products that should be applied* include legal, practical and environmental aspects. The legal issues are related to the use of products, whose compounding AS is authorised to be applied in the EU (listed in the Annex I of the Directive EEC 91/414), approved at national level for the control of the target apple pest or disease, and in some cases suggested for IP. Practical matters imply that the product is effective, has a reasonable price and is ease to handle with. Environmental aspects are associated with the observation of the harvesting intervals to avoid excess of MRL, the alternation of the modes of action (i.e. systemic and contact) to avoid resistances and the consideration of side-effects on non-target and beneficial organisms.

The *dose rates that are recommended* correspond to those indicated on the label of the plant production products. This practice is based on the fact that for the authorization of plant protection products is necessary to ensure that those products, when properly applied for the purpose intended, are sufficiently effective and have no unacceptable effect on plants, influence on the environment and no harmful effect on human or animal health or on groundwater. Properly applications regard to the principles of good plant protection practice and (whenever possible) of integrated pest control.[11]

In **K-UK** some advisers adjust pesticide label recommended dose rates according to the structure of the orchard (e.g. tree density, tree height and foliar density), the growth stage and the characteristics of the sprayer. The adjustment of the doses is backed up by research trials, whose results have achieved dose reductions of even 75% of the full dose. As a part of a project called Pesticide dose Adjustment to the Crop Environment (PACE), a website is available at http://pjwrc.co.uk/DoseRateCalculator.aspx where fruit growers can feed data into the computer and obtain an adjusted recommended dose according to the particular characteristics of their farms and equipments of application.

3.1.1.2. Configuration and characteristics of the advisory networks

The scope of the advisory networks is divided in three operational ranges, a productive sector one, where the investigation that provides applicable alternatives and solutions (e.g. estimation of thresholds for emergent pests, evaluations of pesticide resistances and efficacy of pesticide products, development of application techniques, etc.) to improve the current crop protection strategies implemented in fruit production is conducted; a regional one, at

[11] Council Directive concerning the placing of plant protection products on the market (91/414/EEC)

which general instructions (e.g. by means of warning systems) are provided for the whole fruit growing area; and a local one, where specific plans of pest control or disease prevention are designed upon the particular conditions of the farms and the orchards. Furthermore, advisory networks are recognized as being of public (official), private or mixed (official and private) nature.

- AT THE PRODUCTIVE SECTOR LEVEL

Both in **L-ES** and **ER-IT**, research in crop protection issues is leaded by public organisations (UdL and Università di Bologna) together with a private institute, which also has a public participation (Institut de Recerca I Tecnologia Agroalimentàries in Catalonia and Centro Ricerche Produzioni Vegetali in Emilia-Romagna).

In **LC-DE**, the KOB foundation, which was created by 6 public (Universität Hohenheim, Ministerium Ländlicher Raum Baden-Württemberg, administrative districts Ravensburg, Bodenseekreis and Konstanz and the producer organisation Landesverband Erwerbsobstbau) and private (marketing organisations: Marktgemeinschaft Bodenseeobst and Württembergische Obst-und Gemüse-Genossenschaft) sponsors, deals with investigations on fruit production.

In **K-UK**, the Horticultural Development Company - HDC, which is funded with contributions made by the producers (i.e. a percentage of the turnover), coordinates the research in topical subjects for the fruit production. The investigations are conducted by specialised horticultural research stations (e.g. EMR) and marketing organisations.

In general, research topics are oriented to find solutions to those problems faced during the growing season and the results of the investigations are communicated through the websites of the research institutes, leaflets, brochures, articles in specialised magazines, field days among others.

- AT REGIONAL LEVEL

Similar composition is found in **L-ES** and **ER-IT**, where public agencies coordinate the regional warning systems. The Servicio de Sanidad Vegetal - SSV makes available information through its homepage (a recorded message is also available) for three climatic zones of Lerida. Likewise, the SF provides recommendations for the 9 Provinces of the Emilia-Romagna region. In addition, some pesticide manufacturers publish via internet advices to control key pests and diseases with their products.

In **LC-DE** the constellation of actors providing technical information about regional strategies of crop protection is large and of different nature. A public agency, the district agricultural office (Landwirtschaftlichesamt der Landkreis); three types of private companies: pesticide manufacturers, marketing organisations and cooperatives that commercialise agricultural inputs; and a foundation of mixed origin (public and private): the KOB. All these actors utilise at least one of the following channels for advising growers: faxes, internet websites, bulletins, sms's and recorded phone messages. Coordination of activities and recommendations was not identified.

In **K-UK**, marketing organisations produce regional advisory guidelines for their suppliers; supermarkets do not give advise but ban the use of certain pesticides and the research community together with the Department for Environment, Food and Rural Affairs of the UK have produced the best practice guide for apple production in the UK. Here, it is important to make noticeable the absence of direct actions from pesticide manufactures (which are common in the other regions), the sell of pesticide inputs is made for companies that also offer consultancy services.

- AT FARM LEVEL

In **L-ES**, the recommendations upon the specific conditions in the orchards are produced by specialised technicians of the called Asociación de Defensa Vegetal (Plant Protection Group) – ADV, which could either be established by a grower association or be an independent group. Actions of technicians and discussion of relevant issues are coordinated by the SSV. Pesticide dealers are also involved in field observations and advisory tasks. All persons giving advices in plant protection issues should have a degree in agronomy, preferably have specific experience, be in constant updating and training, and adjust the technical support to the crop and climatic conditions.

In **ER-IT**, the system works in a similar form as in L-ES, the SF has a comparable role as the SSV, at provincial level, a coordinator helps to organize the action of the technicians. Advisors who work for growers' associations or cooperatives should hold a master degree or high school diploma in agriculture and attend an IPM course, which is organised by specialists.

In **LC-DE**, there are five different sources of specific advices. The KOB as well as the advisers of the district agricultural office produce information for some farms; marketing organisations give advise to their suppliers; pesticide dealers make recommendations to some growers; and some fruit producers hire the services of private advisors. For giving advises in issues related to use of pesticides, technicians should prove their competence, by certifying a degree in agricultural education.

In **K-UK**, field level recommendations are obtained from the technical staff of marketing organisations, private advisors or personnel of consultancy companies. These consultancy companies offer two services, which can be obtained independent of each other, the supply of inputs (e.g. pesticides) and the advice-giving. In this region, personal occupied exclusively on supply of chemical inputs (pesticide dealers) are not present. Advisors in the UK should hold a certificate of competence from the called BASIS professional register of managers and pest technicians, for which a continuing professional development through the participation in training programmes is required in order to maintain the membership.

3.1.1.3. Coverage

An indication of the coverage of the advisory networks by means of recommendations made upon the specific conditions of the orchards may be associated to the area under fruit production that is assisted by technical advisors of the ADV in **L-ES** (about 66% of the area), of the growers' associations and cooperatives in **ER-IT** (between 60 and 65% of the area) and of marketing organisations in **LC-DE** (circa 84% of the area). In **K-UK**, 85% of the area under fruit production is certified with the AP.

3.1.2. Growers and farm workers training and capabilities

3.1.2.1. Capabilities

Every person who makes an application of pesticides should dispose of a licence, by which is officially certified that the *required training on management and application of pesticides* has been completed as well as a mandatory test has been approved. Normally, for the application of products with high hazardousness such as these catalogued as very toxic (T+), toxic (T) or harmful (Xn) a special licence is required.

In Catalonia, **Spain**, the applicators' licence (carnet d'aplicador i manipulador de productes fitosanitaris) is issued by the Department of Agriculture, Food and Rural Action with a validity

of 10 years[12]. A basic level licence is mandatory for persons who apply or manipulate pesticides, while an advanced level one is compulsory for persons in charge of technical staff, persons who sell pesticides and workers that make applications for third persons. For the application of toxic products, a licence of fumigator level is required.

In **Italy**, the departments of agriculture of the provincial administrations issue the licence for manipulation and use of pesticides. In the case of products classified as very toxic, toxic or harmful, which represent 52% of the pesticides in the market[13] such licence (Patentino per l'acquisito dei prodotti Fitosanitari in Emilia-Romagna) is valid for 5 years and granted to persons who hold an agricultural degree or take part in a training course and approve a test. For the renewal, to take part in an updating training is compulsory.

In **Germany**, the certificate of competence (i.e. knowledge of technical arrangements and skills) in use of pesticides (Pflanzenschutz- Sachkundenachweis der Anwender) is issued by the agricultural department of the administrative districts. For the management, trade and use of very toxic and toxic products is required to hold a degree in agriculture or homologate it through an advanced training, which is evaluated with a final test. The test includes topics such as integrated crop protection, crop pest and diseases, indirect crop protection measures, properties of pesticides, techniques and equipments of application, first aid in case of intoxication, measures of protection during application, store of pesticides and relevant legislation. Technical advisors and pesticide dealers are also obligated to hold this certificate of competence on use (manipulation) of pesticides[14]. The certificate has an indefinite validity. However, updating and continuing training is required under the certification schemes of GAP.

In the **UK**, there is a central register of sprayer operators called NRoSO[15]. The membership is renewed, if the affiliated participate in ongoing training, courses and events and thereby accumulate at least 30 points on continuing professional development in three-year period. Affiliates should guarantee that they use equipment in accordance with current legal dispositions, are aware of environmental impacts, give priority to the health and safety of humans and animals and care for protection of the farm workers. To be a NRoSO member is a requirement within the Assure Produced Scheme.

Encouraged in large proportion by the requirements of the different schemes of GAP, fruit growers are asked to *take part in various courses of instruction or training* during the year (time for which the certification is valid). The topics discussed and presented during these meetings might be directly linked to crop protection (e.g. techniques of application, control of key problems, new technology, effectiveness of pesticide products, etc.), and also related to other relevant crop growing thematic (e.g. irrigation, fertilisation) as well as management topics (e.g. quality systems). In the four regions, during the cropping season (April – October), few instructive meetings related to crop protection are hold and they are generally focused on relevant problems faced in the crop season. Besides these meetings, up-dating information is also transferred by means of announcements, bulletins, and instructions on the field. In autumn and winter, important subjects of farm management and crop production are presented in colloquiums and meetings, which could be intensive in terms of duration and attendance. Organisers of these events include research organisations (e.g. HDC, KOB), growers associations, public agencies that coordinate the advisory service (e.g. SF, SSV),

[12] http://www10.gencat.net/sac/AppJava/servei_fitxa.jsp?codi=13839
[13] Guida al patentino per l'acquisto del prodotti Fitosanitari in Emilia-Romagna (version 1.1/2008)
[14] http://www.bmelv.de/cln_045/nn_750588/SharedDocs/downloads/04-Landwirtschaft/Pflanzenschutz/Pflanzenschutz-Sachkundeverordnung,templateId=raw,property=publicationFile.pdf/Pflanzenschutz-Sachkundeverordnung.pdf
[15] http://nroso.nptc.org.uk/

fruit marketing organisations (e.g. Marktgemeinschaft Bodenseeobst) and training organisations accredited by the competent administration for accreditation of GAP or regional IP schemes.

3.1.2.2. Efficacy of the applications

The effectiveness of the pesticide application depends not only on an accurate estimation of the necessity of implementing a control strategy, but also on performing an efficient application in terms of timing, technique and equipment of application that guarantee the production of drops of adequate size that reach the target.

In the practice, the *application of pesticides in the recommended dates* may be limited by climatic conditions (e.g. in a rainy day the use of tractors will be limited as soil conditions can be negatively affected and in addition pesticide products may be washed up), labour capacity (e.g. the no-disposal of spray operators, the requirement of the tractor for other farm operations) and farm structure (e.g. when the size of the orchard is very large, the application of pesticides can not be carried out in a single day or immediately).

The *modernity, maintenance and calibration of the equipment* define the quality of the pesticide applications. Basic tasks within a calibration procedure include the adjustment of the speed of application, the nozzle volume to produce drops with adequate size to reach the target and the pressure of application. In the last decades, the *techniques in application of pesticides* have been characterised by reductions in the volumes of application. However, estimations of the modernity and renewal periods of the machinery are difficult to assess.

For all the growers, whose production is certified under a GAP schemes or regional principles of IP, periodic test and regular calibration of the equipments utilised for the application of pesticides are compulsory. These inspections include technical parameters and the security of the operator and the machine. The no-observance of the points of control may be classified as a slight infringement (e.g. problems with a filter), which implies an immediate correction or as a serious infringement (e.g. problems with the manometer) for which a period for correction is given. In the case that the inspection is unsatisfactory, the certificated of inspection can not be issued.

In **L-ES**, the Center for Agricultural Mechanisation of the Department of Agriculture, Food and Rural Action of Catalonia is in charge of carrying out that inspection of equipments. A sticker confirming the approval of the inspection is put on the machine. The inspection is due to be done every four years.

In **ER-IT**, the Directorate of Agriculture of the regional government authorises competent agencies for the tests and maintenance of the equipments of application. A certificate of inspection is valid for five years for machinery used only in an independent orchard and for two years for those equipments used for applications on farms belonging to third persons.

In **LC-DE**, the Plant Protection Service of the Federal State Baden-Württenberg, the district administration of Stuttgart and several agricultural boards coordinate the inspections of the application equipments, while the tests are conducted by approved agencies. The district administration is in charge of the recognition of the centers for inspection and supervision, the agricultural boards are responsible for the execution and the Plant Protection Service gives the training required to experts of the recognised agencies. The equipment of application must be checked every two years, after a satisfactory revision a report of the test is produced and a sticker is put on the machine.

In the **UK**, according to the standards of the AP, the equipment used for the application of pesticides must be checked every year under an independent officially recognised system for inspection of sprayers, which grants a valid approval certificate. Furthermore, the machines

must be maintained at least annually and a guarantee issued by an engineer certified by the manufacturer of the appliance is also required.

3.2. Socio-economic factors that affect plant protection strategies

3.2.1. By influencing the content of the technical advices

Crop protection strategies and PU shares in terms of quantities of insecticides or fungicides are different in each region because the *pest and diseases problems* depend on the climatic conditions. Today, stakeholders involved in crop protection research and PU decisions possess vast knowledge about the biology, epidemiology and occurrence of pests and diseases in each region.

From the information about the flights of *Cydia pomonella,* which is a common pest in European apple production, is possible to confirm that its relevance in **L-ES** is high (3 generations), while in **ER-IT** (2–3 generations) and **K-UK** (2 generations) is intermediate and in **LC-DE** (1–2 generations) is low. Accordingly, the tactic strategies to control this insect change in intensity among the regions. The incidence of a non-typical apple insect in **L-ES**, the *Ceratitis capitata* demonstrates that crop protection strategies must be designed upon the particular geomorphologic and climatic conditions of the regions.

The *AS that are authorised to be placed on the market* and used in agricultural production in the EU are included in the Annex I of the Directive 91/414/EEC. An AS is listed in this annex after going through specific studies within a defined registration process, by which is technically demonstrated that the pesticide does not have harmful effects on humans (consumers, growers, community), does not produce unacceptable effects on the environment when properly used. At country level, pesticide products (containing authorised AS) are approved for their use in specific crops, against specific pest, disease or weed problems, and in a defined quantity. Instructions of use, hazardousness information and recommended application doses are included in the label of the products. In the practice, applications of quantities below these recommended rate-doses may be effective, if specific conditions of the fruit production (e.g. vegetative period of tress, orchard structure) are taken into account. On the contrary, applications exceeding these recommended doses would cause pesticide resistance problems.

In the last two decades, with the implementation of the Directive 91/414/EEC, the registration of the AS authorised has been revised. Resulting from that process of revision, the amount of AS available has been reduced and the properties of the products that can be put on the market have been adjusted. The regulations adversely affect new pesticide introductions but encourage the development of pesticides with fewer toxic side effects (Ollinger and Fernandez-Cornejo, 1998). The Regulation on placing on the market plant protection products besides to the strict criteria for approval of pesticides also specifies a mechanism for substitution of more toxic pesticides by safer alternatives including non-chemical alternatives.

The FDSUP includes a new criterion for approval of AS including toxicity and environmental “hazard triggers”. The Pesticide Safety Directorate of the UK calculated that 68% of the insecticides, 31-43% of the fungicides and 25-31% of the herbicides could fail in the re-approval, if the cut-off criteria are implemented. While, the German Ministry for Consumer Protection and Food Security (BVL) calculated that 90% of the insecticides would be affected.

In order to reduce the quantities of pesticides needed to make an effective crop protection labour, biological, cultural and technical tactics have been identified and included in diverse guidelines of IP and standards of GAP under the definition of preventive and monitoring

tasks. When a direct control strategy is required, the use of pesticides is the last option, after considering the *available non-chemical alternatives*. Economic (e.g. price), technical (e.g. application timing, weather conditions, farm structure and localisation) and a legal aspect (e.g. authorisation of bio-control tools) are decisive for the selection and use of non-chemical alternatives.

Limitations to the use of non-chemical alternatives in control of *Cydia pomonella* in **L-ES** include: that the price of bio-control methods is higher than the cost of treatments with conventional pesticides; that the implementation of these alternatives is time and labour demanding as additional tasks are required (e.g. monitoring); that matting disruption is an effective technique, when used to control the first generation of the insect, but for the second and third generations of the insect, the use of conventional pesticides still required; that high temperatures and strong solar radiation (in hours of exposure and intensity) negatively affect the use of granulose virus, as the product is easily evaporated; that the massive (communal) implementation of sexual confusion techniques and of field borders' controls, which enhance the pest control effectiveness are discouraged by the structural attributes of the factors of production (i.e. small orchards located away from each other); that effective bio-control tools used in other EU countries can not be homologated, according to the Regulation on the authorisation of biocidal products and compounds (Directive 98/8/EC); that the registration costs of new products (e.g. a granulose virus obtained from a same virus, from which a product has been already produced but faces resistance problems) are high.

The *Common Agricultural Policy of the EU seeks to foment the rural development* (Article 69) by enhancing the competitiveness of the farmers. For that, strategies such as investment on equipments, training and implementation of innovative farming systems are supported. Member States and Regional Authorities should establish the financing plans.

The implementation of alternative techniques of crop protection for pests puts into quarantine and the encouragement of collective actions are supported by means of subsidies, which are ruled by the Regulation CE 1857/2006. For instances, In Catalonia, **Spain** the control of the *Cydia pomonella* (Orden AAR/359/2008) was declared as an obligation. Consequently, the material used in sexual confusion is subsidised with 100 €/ha and labour costs with 50 €/ha (or maximum 50% of the costs). In the case of the *Ceratitis capitata,* another pest put into quarantine (Orden AAR/359/2008) subsidies of material and labour used in pest control are of maximum 200 €/ha (or maximum 50% of the costs).

The EU Regulation CE 2078/1992 was introduced to support specific cropping techniques aiming at reducing the use of chemical inputs. The EU Regulation CE 1782/2003 establishes common rules for direct support. In 2005, the average support for agri-environmental measures in the EU was about 97 €/ha (103 €/ha in **Germany**, 154 €/ha in **Italy**, 58 €/ha in **Spain** and 147 €/ha in the **UK**).

As a requirement for the *certification of GAP or regional schemes of IP*, all the pesticide treatment should be justified. It implies that PU decisions should be based on observation of the disease evolution (normally through modelling) and pest monitoring (commonly by means of counting insect's captures and comparing it with pre-established thresholds). The use of officially approved pesticides is a major must control criterion according to the GlobalGAP Crop Base guidelines.

Under the concept of integrated crop protection, the selection of the pesticides products is related to the inherent toxicity and environmental side effects of the legally authorised AS. The International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC) in its guideline for the production of pome fruits in Europe (issued in year

2002)[16] established lists of permitted (green list), restricted (yellow list) and prohibited (red list) pesticides. Today, the *lists of pesticides recommended for IP* are less selective as the amount of AS authorised and available has been reduced and even pesticides that in the past were restricted because they are harmful for beneficial organisms (e.g. pyrethroid insecticides) are accepted for IP production.

Food safety standards are associated with the quality of the fruit and their accomplishment constitute one requirement for the commercialisation of apples. The food safety criterion include among others the detection of low pesticide residues (in some cases fractions of the legally established MRL and limited number of AS) and the prohibition to use of determined pesticides. Although, that the participation in a programme of pesticides residue testing and monitoring is a major must within the GlobalGAP Crop Base guidelines and that it is expected that fruits produced in orchards, where GAP are observed (and certified) would not have problems when the quality controls and MRL tests are conducted, in case of failure, the certification of the production is not an enough argument for the trade of apples.

3.2.2. By influencing the attributes of the advisory networks

In addition to the realisation of payments, which are conditioned to the fulfilment of GAP and the observance of agro-environmental measures, sustainability and animal welfare. The *rural development policy of the EU* counts with other instruments to address the objectives of competitiveness and sustainability of the rural sector. For example, in the fruit and vegetable sector, which is included in the scheme of single payments through the EU Regulation 1182/2007, those producer organisations that help growers to organise and concentrate their supply of fresh products to satisfy the demand (competitiveness) and that assist farmers to apply the best available technology and thereby to become more competitive in an environmentally friendly way (sustainability) may become beneficiaries of the official support.

With the Regulation CE 1857/2006 is not only regulated the subsidisation of material and labour needed to control pests put into quarantine, but compensations to support services of technical assistance in minor agricultural exploitations are also ruled. Then, a percentage of the honoraries paid to advisors may be funded.

Private schemes of certification on GAP demand that technicians responsible for IP advice and selection of pesticide products should receive specific training or demonstrate their technical competence. Within the crop base guideline of GlobalGAP, a compliance criteria of minor level is fulfilled, if IP advisors have the required qualifications. While, competent advise for the selection of pesticide products is a major must.

3.2.3. By influencing the capability of fruit growers and farm workers

The *Common Market Organisation for fruit and vegetables* aims among others to improve the competitiveness and market orientation of the sector and to enhance environmental safeguards (rules are laid down in the Regulations CE 2200/96 and CE 1182/2007)[17]. Some of the measures offered to achieve these objectives are the foment of producers' organisations, the integration of the sector into the single payment scheme, promotion of organic production and elimination of export subsidies.

Training and certification of the competence on application of pesticides are instruments that not only act to reduce the risks to users of agricultural chemicals, but also contribute to enhance the sustainability of the agricultural production. Under the Fifth *Environmental Action Programme of the European Community* with the aim of reducing PU, training activities in integrated control were fomented. Supports were launched for implementation of

[16] http://www.iobc.ch/pomme_fruit/Pome_Fruits_ENGLISH.pdf
[17] http://ec.europa.eu/agriculture/capreform/fruitveg/index_en.htm

integrated environmental programmes at farm level through voluntary contract with regional authorities concerning environmental aspects of the agricultural production (implementation of environmental programmes at farm level is ruled with the Regulation CE 2078/92). In the *National Pesticide Law*, requirements for the certification of competences in use of pesticides are set and restrictions to obtain pesticide with high hazardousness are specified.

Similarly, requirements considered in *private schemes of certification on GAP* put more emphasis on demonstration of technical qualification of growers and farm workers in pesticide use than in specific training in this topic. In the All Farm Base guidelines of GlobalGAP to demonstrate the capability of spray operators is a major must. While, to attend training activities is a minor must (guidance in safety and health is expected).

3.2.4. By influencing the effectiveness of the pesticide applications

Policy instruments can have an effect on the efficiency of the pesticide treatments by enhancing the quality of the applications (e.g. calibrations, inspection and upgrade of equipments of application) or encouraging self-control of the farm operations (e.g. keeping records of the pesticide applications).

An action that has been implemented to foment the rural development, which is an objective announced (Article 69) in the *Common Agricultural Policy of the EU*, is the support to investments on machinery. This action has been materialised though mechanisms such as national programmes of technology subvention, support to young farmers and innovation plans. Estimations of the average technological level of the appliances utilised in application of pesticides in one region are difficult to assess, because there is not an obligation to inscribe the equipment in an official inventory, except for beneficiaries of programmes that support investments in technology who should register their machinery in an official database (e.g. In Catalonia, **Spain** in the Registro Oficial de Maquinaria Agricola).

One of the principles that guide the *community regulations for hygiene in the food processing industry* is that is necessary to guarantee alimentary security throughout the food production chain, starting from alimentary production. Consequently, the Regulation CE 852/04 includes parts of the called safety programme and introduces a mandatory practice of auto-control in the agricultural production. It implies that all the treatments and practices performed in crop growing (such as PU) should be registered. The FDSUP introduces a mandatory record-keeping throughout the production chain.

The maintenance and adjustment of the machinery utilised for pesticide application is encouraged through *private schemes of certification on GAP*, however, it is a slight enforced procedure. Although, justifying and documenting pesticide applications are compulsory tasks to obtain a certification on GAP in production, more emphasis (compliance criteria and level of control points) is put on information related to safety standards (e.g. harvesting interval) than on traceability (e.g. machinery employed).

In the Crop Base guidelines of GlobalGAP, to keep the machinery utilised for application of pesticides in a good state of repair and to certify that a verification of its correct operation (technical parameters that should be observed during an official inspection of the machinery utilised in the application of pesticides for production of fruit trees are defined in the norm UNE-EN13790) was completed in the last 12 months constitutes a minor must. While, the participation on calibration programmes is just a recommendation. In the same guidelines, a compliance criteria of major must level is that records of pesticide applications include at least data about the crop, variety, area, farm, date of application, product applied, formulation and pre-harvesting period. Providing additional information of the treatments such as names of the operator and the advisors, quantity applied and machinery employed, is a minor must.

3.3. Implications for pesticide use

In the Figure 6, these factors that have been identified from, interviews and complementary information as driving forces of PU decisions by influencing the information given to growers are illustrated.

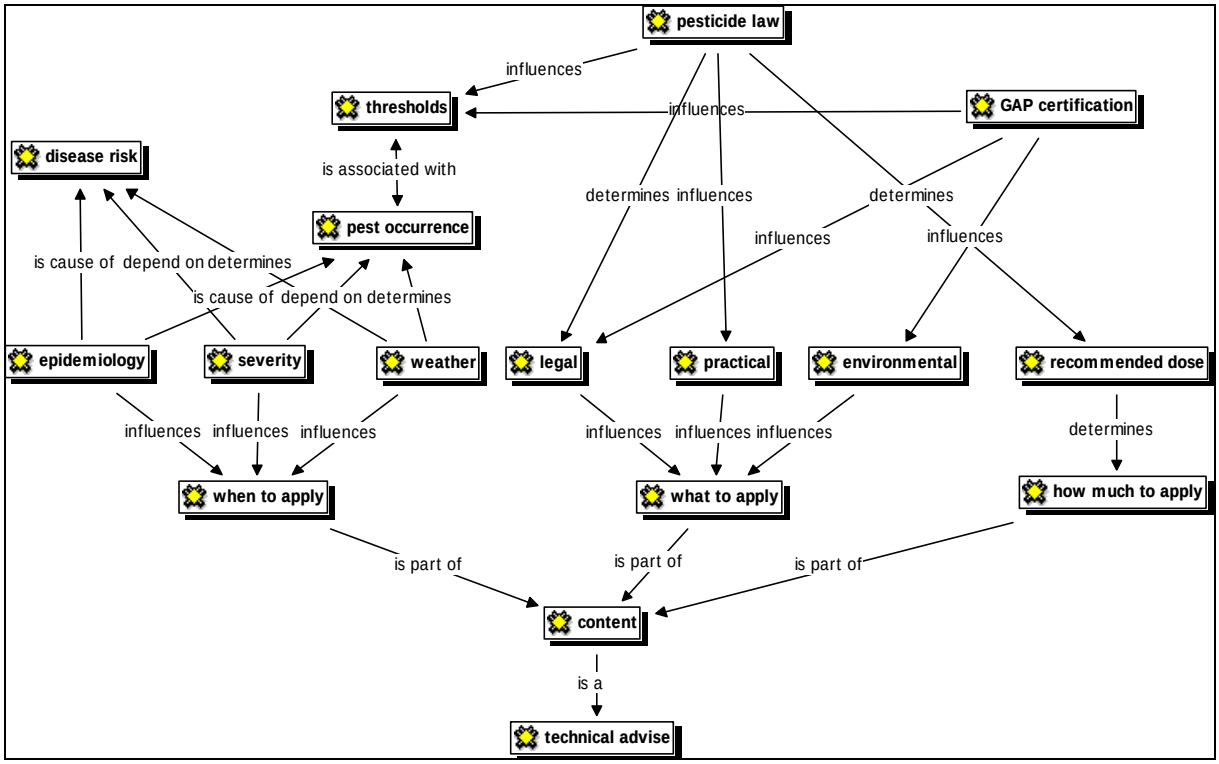

Figure 6. Factors affecting the content of recommendations

In the design of crop protection strategies, in general, the moment to apply pesticides is defined when there is evidence that a disease will outbreak or when the presence of insects exceeds an accepted limit. In other words, PU decisions are made under the idea or common perception that pests should be controlled, while diseases should be avoided. In apple production, problems with weeds are less important, herbicides' use represents a small percentage of the quantity of chemical inputs.

Under the currently on-force regulations, the number of pesticide products that are available on the EU market has been reduced in the last years. With the FDSUP, pesticides classified as very toxic (T+), toxic (T) or harmful (Xn)[18] will be limited as well as those that produce chronic toxicity. On the one hand, it can be taken as a guarantee for the safety of the humans and the environment. However, on the other hand, it may generate problems in the design of crop protection strategies (e.g. pesticides anti-resistance strategies are limited) and could lead to new plant health problems (e.g. problems with secondary pests).

The use of non-chemical alternatives in crop protection depends not only on the availability of biocidal tools, but also on the affordability, efficacy and applicability. Financial support through official programmes, when a pest or disease occurrence represents a critical plant health problem, contributes to cover costs of implementation (material and labour) of the these alternatives and also to avoid risks of creating dependence on use of pesticides.

[18] In Italy, product of these categories account for about 52% of the pesticides available

Nowadays, to practice a crop protection strategy that follows all the technical principles of IP (e.g. implementation of all available non-chemical measures in prevention[19]) is a difficult task. Tactics as the selection of pesticides according to their hazardousness and environmental externalities are limited, the choice of products depends more on what is available on the market. Selecting pesticides becomes even more restricted when a low number of reportable AS and fractions of the legally set MRL are demanded. Similarly, the observance of harvesting intervals (to avoid MRL excess) and the ban on use of certain products imposed by fruit retailers (supermarkets) have an effect on the decision about the products that should be applied.

These factors affecting PU decision by influencing the properties of the advisory networks that were identified from interviews and complementary information are depicted in Figure 7.

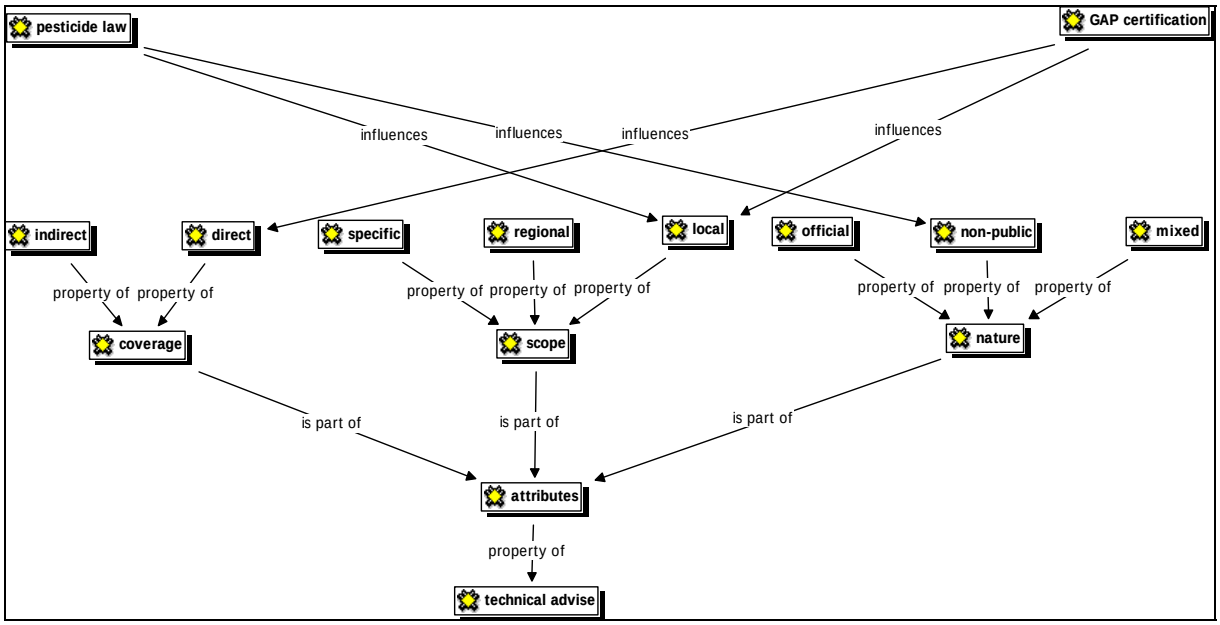

Figure 7. Factors affecting the attributes of the advisory networks

Independent of the nature and scope of the advisory networks, in each region knowledge adapted to the particular climatic conditions is generated. For the design of crop protection strategies, the coverage and the provision of information produced upon the characteristics of the orchards are determinant. The coverage of the advisory networks in terms of this type of direct effect consultancy is significant (at least 65% of the area under apple production) and has a positive incidence in applications to obtain a certification of GAP according to norms set by private schemes.

The use of advisory services may be encouraged through official funding, if a pest or disease is declared in quarantine. The implementation of public supported programmes that foment producer organisations as a strategy to enhance the competitiveness of the rural sector may generate changes in the nature of advisory networks. Within private GAP certification schemes, qualifications and competences of the advisors are mandatory requisites.

In Figure 8, factors identified in interviews and complementary information that affect the capabilities of fruit growers and thereby influence PU decisions are shown.

For all the fruit growers and farm workers who manipulate and apply pesticides, competence on pesticide applications is compulsory. Knowledge of crop protection issues, which enable farmers to make accurate decisions and act to reduce the risks for humans and the

[19] Guidelines for Integrated Production of Pome Fruits in Europe (IOBC, 2002)

environment, is acquired through training and education. Up-dating is commended by private schemes of certification on GAP (however, pesticide use is not necessarily the main topic) and also included in public supported programmes aimed at enhancing the competitiveness (by supporting producer organisations) and sustainability (by implementing environmentally friendly farming systems) of the rural sector.

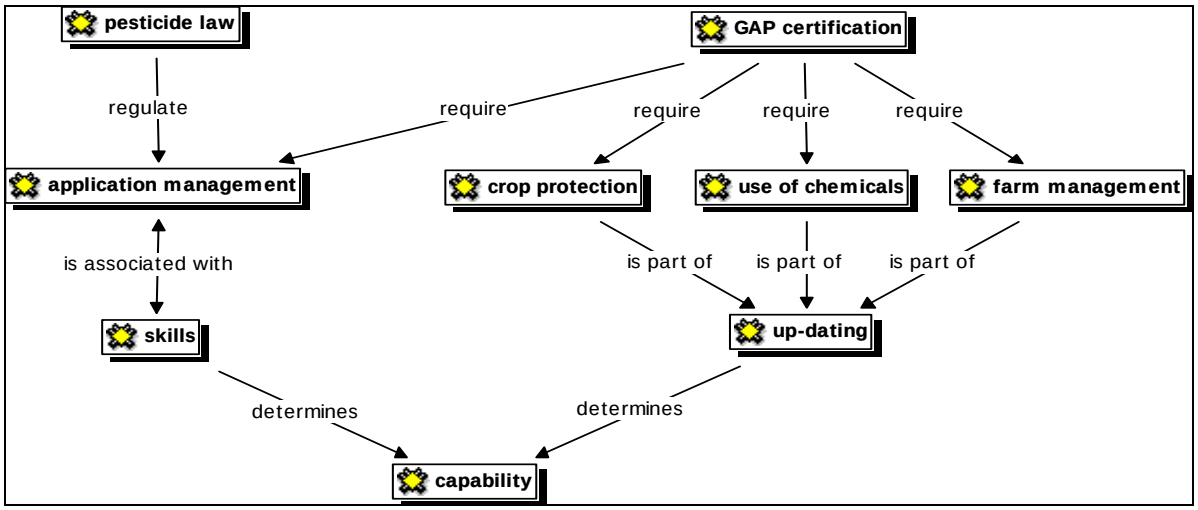

Figure 8. Factors affecting the capabilities of fruit growers

The Figure 9 contains factors that were identified in interviews and complementary information that influence the efficacy of the pesticides applications and consequently PU choices.

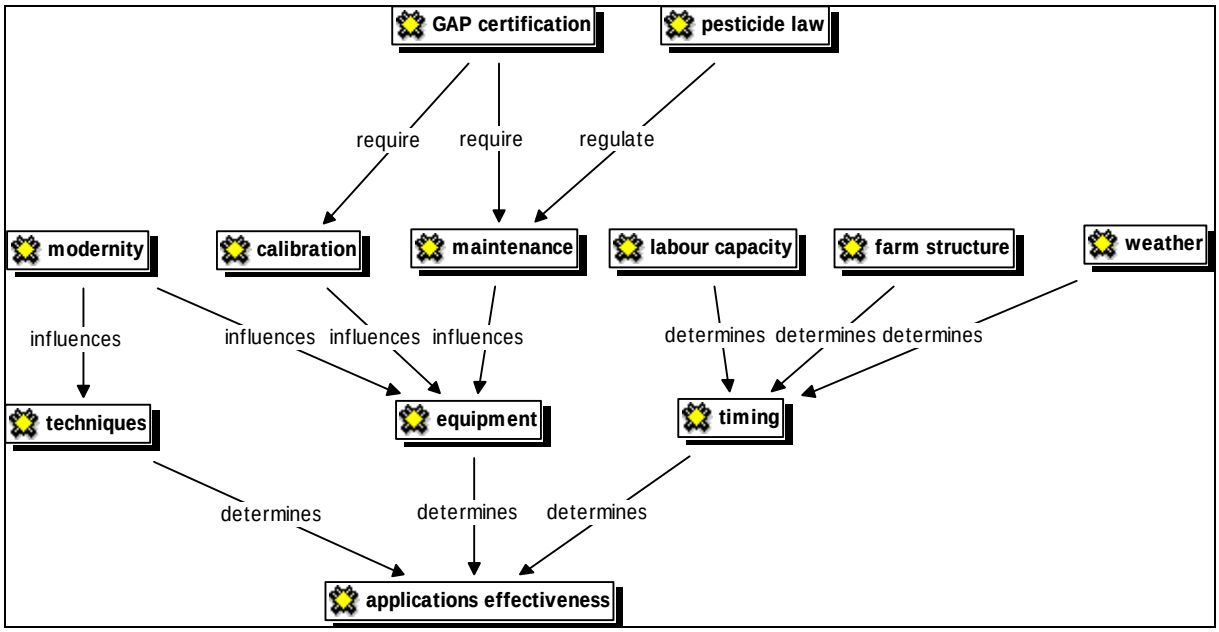

Figure 9. Factors affecting the effectiveness of the pesticide application

The effectiveness of the applications of pesticides is more related to farm operations than to PU decisions. Public interventions have a greater contribution in renovation of the machinery. While private schemes of certification on GAP encourage activities that make possible to improve the quality of the applications such as the periodic revision of the appliances and the voluntary and regularly calibration of the equipment of application.

On the market, food products that do not represent a risk for consumers, which is linked to an acceptable amount of pesticide residues, are demanded for. Consequently, certification

schemes that guarantee that the production has been performed according to specific parameters (GAP) have acquired importance. One element to prove the traceability of the fruit production activities is the record-keeping. Indeed, it is not a factor that influences PU decisions, but it is an instrument to control PU.

3.4. Socio-economic driving forces of pesticide use decisions

3.4.1. When fixing the quantity of pesticides

Tactic solutions that are put into practice are grounded on the common perception that diseases should be prevented and pest controlled. Thus, higher use of pesticide quantities takes place in regions with high pressure of diseases, specifically *Venturia inequalis* and *Erwinia anylovora* (**LC-DE** and **ER-IT**). In regions where low intensity of PU is implemented, pressure of disease problems is lower due to climatic conditions (**L-ES**) or the apple production is more extensive (**K-UK**).

A rational use of pesticides is currently implemented. Regional strategies of crop protection are made upon very well developed knowledge of pest and disease problems. Besides that, there are many controls to PU, external ones such as the monitoring of residues (MRL are respected[20]) and internal ones as the mandatory record keeping. With the certification of the apple production by private schemes (e.g. GlobalGAP), factors related to PU such as justifying the needs of performing a treatment, obtaining advises to choose products from qualified consultant and advisory service, and carrying out of the applications by trained personal are guaranteed.

The instruments of the agricultural policy of the EU that are today implemented are not directly aimed at reducing pesticide load (kg AS/ha). However, these instruments, by which the agricultural production is supported, while addressing multiple objectives, may contribute to achieve a rational use of pesticides. for instances, by enhancing the competitiveness of fruit growers and the sustainability of the production. In some cases, the particular issue PU may not be directly addressed, because sustainability is a term with a broad definition (e.g. making appropriate water management, applying practices that do not harm the soils, etc.).

In both, technical recommendations and compliance criteria of guidelines set by private schemes of certification on GAP, priority is given to food safety standards according to market requirements, which are mainly aimed to guarantee reductions of risks to consumers from pesticide residues.

Technical options to reduce pesticide load still possible. Some tactics are, making use of all the available strategies of crop protection, for instances, by growing disease resistant varieties; adjusting dosages upon orchard characteristics; performing properly and periodic calibration of the equipment of application.

In conclusion, PU quantities are influenced by the common perception behind the tactical strategies of crop protection, the prevention of diseases and the control of pests. PU decisions are made upon commercially set GAP to obtain fruit with marketable food safety standards.

3.4.2. When choosing the type of pesticides

In regions where farming systems are characterised by the use of pesticide products with novelty properties, levels of certification with regional IP standards are significant (in **K-UK** is equivalent with the private certification scheme on GAP and in **LC-DE** is the standard system

[20] in 2006 in Italy, 6000 MRL tests were conduced, 65.8% did not present residues, 32.7% had MRL permitted by law and 1.5% exceed the MRL (Italian Ministry of Health)

of production). However, it does not mean that regional certification on IP is influence the selection of pesticide products. In the practice certification with regional IP schemes is limited as its commercial function also is. This assertion may be confirmed with the fact that just 12% of the fruit produced in **ER-IT** is traded with the IP regional label, but in this region 45% of the fruit production area counts with the label "Qualità Controllata" (Canali, 2008).

In regions where crop protection strategies are typified by the use of conventional pesticide products, the insect pressure (e.g. in **L-ES** *Cydia pomonella* and *Ceratitis capitata*) is higher. In control of pests, the availability of chemical solutions is more limited. Thus, with the limited availability of insecticides and the necessity to alternate products as a part of the pesticides' anti-resistance strategies, the observance of toxicity of the products and potential environmental externalities are not decisive factors in the selection of the type of pesticide that should be applied.

Private schemes of certification of GAP represent the market requirements, which have as a main concern the risks to consumers of food with residues. Accordingly, partial MRL and few number of reportable AS in fruit have been set as food safety standards. In these schemes, awareness of risks to users of agricultural chemicals is also taken into account.

Accepting legally authorised pesticides may have good efficacy and produce tolerable effects when used properly and that the legally set MRL in fruit are a guarantee for consumers, research efforts should be oriented to improve and implement appropriate techniques of application and development of sustainable systems of production.

In conclusion, the selection of pesticide products is made according to the parameters set in private schemes of certification on GAP and adjusted to the availability of products (being critical in the case of insecticides) and alternatives in order to attain fruits with a quality that is commercially accepted. The priority in the selection of pesticides is that risks to consumers of residues are reduced.

Recommendations

For extensions services

Several elements of crop protection strategies have been produced and related to properly use or implementation of GAP. The labour of extension services is to foment and put into action the best possible techniques and systems of productions that fit in the local conditions. Furthermore, advisors have an advantageous position for detection of up-to-date topics that are relevant for crop protection and should be studied (e.g. outbreak of secondary pests).

For crop protection researchers

Under the current circumstances (e.g. less products are available, pesticides are more specific, high demand for fruit of commercial quality), technical problems of production arise when avoiding the generation of resistances and the control of secondary pests. For these purposes estimations of thresholds and foment of natural predators are needed. For example, successfully control of *Panonychus ulmi* has been achieved in **K-UK** through the action of the natural predator *Typhlodromus pyri*.

Other important topics of research are the performance of tests of pesticides' effectiveness as well as the establishment of the most appropriate timing and conditions for the application and use of non-chemical strategies.

Policy relevant for pesticide use decisions

Current state of pesticide policy

The European legislation regulates the authorisation and put into the market of AS and pesticide products. Similarly, controls to PU at the end of the production process are clearly defined by means of the rules about MRL. Improvements are pretended with the FDSUP, for instances, with the cut-off criterion (e.g. carcinogenic, mutagenic and hormonal effects) for the approval of AS and the creation of three zones where mutual recognition of authorisation of products is mandatory, and with the put into force of the Regulation on homogenisation of MRL that are legally accepted in food.

Perspectives of pesticide policy

In the FDSUP, regulations on use of pesticides during the crop production process are stipulated with the announcement that up 2014 all the agricultural production should be done under IP principles.

In the case of the apple production, the adoption of integrated systems across Europe is challenging. Most of the certification of the production process is done by the private sector and diverse quality assurance schemes have been established[21]. Although, in these private certification schemes the use of pesticides is also considered, safety, hygiene and correct handling play a more important role than the implementation of all the technical instruments to reduce their use. For commercial purposes, the results obtained by implementing safety standards are easy to communicate and convincing. In other words, it is simple to understand that a fruit does not have any pesticide residue (however some products were actually applied). Whereas, to affirm that a pesticide was used in a rational way seems to require an extra explanation.

Complementary legislation

At EU level, certification bodies should be accredited in accordance with the norm UNE-EN45011. Then, National Entities for Accreditation evaluate the technical competence of each certification body on guaranteeing that a grower (and processors) is able to produce agricultural outputs by following the principles included in a technical norm. In the evaluation of certification bodies, aspects as the qualifications of the advisors, the fulfilment of the defined procedures during auditing process, and the independence, impartiality and integrity are evaluated.

In practice, cross compliance policies have helped to increase the coverage of the advisory networks and the use of decision support systems by fomenting the supply of technical recommendations. Complementarily, the implementation of sustainable productive systems, including communal adoption of crop protection strategies (e.g. sexual confusion) has been promoted. However, the wide range of the sustainability concept may act to displace the rational use of pesticides within the cropping system and give more importance to other topics such as the sustainable management of water and soil, less emissions of gases that contribute to the global warming, etc.

[21] In 2006, diverse quality assurance schemes (QAS) and large scale retailers' certifications (LSR) were identified under a project leaded by the European Commission (e.g. in Germany: 25 QAS and 5 LSR, in Italy: 24 QAS and 9 LSR, and in the UK: 28 QAS and 4 LSR) http://foodqualityschemes.jrc.ec.europa.eu/en/documents/ReviewReport_000.pdf

Policy options

A policy option is to accept the self-regulation of the apple production chain and thereby the standards enforced by the fruit retailers and marketing organisation, where safety issues (e.g. zero residues production) in use of pesticides have priority over the use of all technical alternatives of crop protection (e.g. use of disease resistant varieties).

For the implementation of IP schemes from 2014, it is necessary to define a baseline, where the main concern given to the use of pesticides (e.g. from FDSUP: to ensure that consumers and animals are protected from pesticide residues in feed and food, to reduce the overall impact of pesticides on health and the environment, to reduce the usage of pesticides) and the strategies are defined (e.g. from FDSUP: low-input agriculture, pesticide-free cultivation, certifying codes of good practices, agricultural payments, foment of training and applied research, improvements in the quality and efficacy of the equipment of application). Keeping the commercially set standards for fruit production requires that the state should confirm that trade barrier are not imposed and that the communication is truthful and according with the laws. On the other hand, changes of objectives would imply that the state has to assume the labours that the private sector is performing in certification of process to guarantee the implementation of defined standards of production. This change is costly and also requires of adequate institutional capacity.

Finally, it is important to mention that the European Commission has undertaken a consultation exercise called “Green Paper”[22] to investigate whether the existing agricultural products’ standards, farming requirements and quality schemes at the EU level are adequate, or how they could be improved. Food growers, representatives of non-governmental organisations, processors, retailers, distributors, traders, consumers and government employees are expected to take part in the debate.

[22] http://ec.europa.eu/agriculture/quality/policy/consultation/greenpaper_en.pdf

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