# QUALITOM, A EUROPEAN RESEARCH PROGRAMME TO BUILD AND TEST A TECHNICAL ITINERARY MODEL IN PROCESSING TOMATO CROPPING

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Abstract

The aim of the programme is to provide farmers with tools and methods which might help in processing tomato crop management in various conditions in order to satisfy all of the following objectives: to produce a given yield of tomatoes, of good market and hygienic quality (given dry matter content, given pH, absence of chemical compounds harmful to human health) for the production of paste; to minimise the use of chemicals for crop protection; to avoid the release of nitrate to the ground; to reduce the production costs. A technical itinerary is defined here as the whole of the reasoning and of the resulting set of decision rules utilized for the application of cultural techniques to obtain a given production (quantity and quality), with controlled effects on the environment and according to social-economic constraints. Based on this definition, a research is performed to construct a model of technical itinerary $TI_{mod}$ to reach the previous objectives in processing tomato cropping for paste. $TI_{mod}$ is expected to be valid in a wide range of constraint sets. It is constructed from knowledge and from some observations of the state of the environment and of the crop obtainable by farmers At present, the construction of $TI_{mod}$ has led to making a set of about hundred rules and subrules and some of them have been formalized in computer softwares. $TI_{mod}$ is being tested experimentally during three years from 1997 by 10 scientific partners from 5 countries, operating in 10 locations in the main areas of processing tomato production in the European Union. Observations are made at various stages of the crop to ascertain whether the anticipated behaviour of the environment and the crop has been achieved. In each location another treatment ($TI_{loc}$) consists in cultivating processing tomato with the same framework of objectives and constraints as $TI_{mod}$, according to a local expert using the current technical knowledge in the given area.

## 1. Introduction

The processing industry increasingly needs raw material meeting defined standards, especially concerning hygiene and technological quality. Moreover, the growers and processors must seek to reduce production costs. Additionally, farming activities must increasingly be respectful of the environment and all natural resources by avoiding the release of biocide molecules and nitrate to the soil and often by limiting water use.

Open field processing tomato is a major crop in the South of the European Union and must both remain competitive and adapt itself to the constraints of the new Common Agricultural Policy. In most cases in Europe, the tomato crops are presently managed to obtain the highest fruit yield. Fertilization and irrigation are often excessive. This can be harmful for the environment (wasted water, leaching of nitrate) and for quality, since the fruit composition (e.g. dry matter content) can greatly vary according to growing conditions (Dumas *et al.*, 1994, Battilani *et al.*, 1994, Christou *et al.*, 1994, Dadomo *et al.*, 1994, Rodriguez del Rincon *et al.*, 1994). Pest and disease control generally results in frequent application of synthetic chemicals. Often systematic spray programmes of up to 15 times spray annually to suppress risks would have undesirable consequence on hygiene quality of the harvested tomatoes and for the environment.

Therefore, the objectives of present investigation for better tomato production for paste are summarized as follows:

- desirable level of the fruit technological characteristics (high °Brix, red colour and low pH) to income growing and processing tomato can remaining competitive.
- good hygiene quality of the raw material for the processing industry i.e. very minimal presence of substances which are harmful to health (pesticide residues and nitrate ions) in the fruit at harvest.
- considerations towards the environment : it is necessary to reduce as much as possible the use of chemical products for crop protection (herbicides, fungicides, bactericides, insecticides) to limit their release into the environment. It is also necessary to seek a lower use of fertilizers, in particular those which supply nitrogen, to reduce the risk of environmental pollution.
- satisfactory level of the balance between production value and costs. The increase in quality should not be at the expense of yield per hectare and farm revenue must be sufficiently high. For a given agronomic result, the aim is to reduce the production costs. This involves labour and technical methods (seed, irrigation, fertilizers, pesticides, harvest conditions...).

A successful crop management of processing tomato within the above frame of new objectives is not easy for farmers, because it requests a complex reasoning based on specific knowledge. Consequently, this reasoning must be translated into decision rules which might be applicable to the particular crops of the farmers. Moreover, when those rules are complex, farmers need tools to manage the rules.

It is no easy task to manage any crop scientifically. However, scientific advances have enabled the practice of reasoned management in some crops, for example, integrated crop protection against some pests in fruit orchards and greenhouse tomato crops. For the sanitary protection of processing tomatoes, the existence of scientific data (University of California, 1998) and various studies (Grieshop *et al.*, 1988, Hoffman *et al.*, 1990) would make it possible to replace synthetic chemical treatment by alternative methods. However, as the weather conditions and parasitic situations in California differ from those in Europe, it would be difficult to use their methods directly in the European production area.

Although tomato has been the subject of many studies on its physiology and on modelling of its functioning, crop management reasoning is still very complicated to perform. Crop management requests to consider simultaneously a great quantity of interacting factors to facilitate decision-making: climate, soil, plant cover, crop techniques, parasitism and environment. Moreover, many are of a random nature, in particular those due to climatic events throughout the crop.

Among the factors which the farmer must deal with, some can be modified by the farmer such as soil moisture, soil chemical status or parasitism. However, some are heavily imposed such as limited water resources and high labour costs and some are fixed such as soil texture. Such factors are considered as constraints.

Thus the subject of the study is the reasoning of tomato crop management for paste production and consequently the establishing of decision rules in order to satisfy the above objectives in a large range of constraints specific to the Mediterranean Basin. A priority is given to the water management, because it is a decisive factor in the tomato production in the Mediterranean region. Water management is also important in controlling over harmful substances in the harvested product or pollution to the environment (pesticide residues, nitrate). Another priority is the crop protection methods. Crop establishment, fertilization and harvest conditions are also considered.

## 2. Materials and methods

### 2.1. General methodology

The approach adopted in the study is represented by a flowchart in Figure 1. Sébillotte (1978) defined the concept of technical itinerary as the logical and organized course of technical actions applied to a cropped species. This particularly applied to the understanding of any specific case of crop management, for instance, the way of reasoning followed by a farmer to cultivate a given field, with constraints. This concept has already been utilized to create and test technical itineraries (Dumas, 1990, Meynard *et al.*, 1996). In the undertaken study, a technical itinerary is more precisely considered as the whole of:

(i) a complete reasoning which must be supported sufficiently by knowledge to define milestones and intermediate cropping goals likely to enable to reach the objectives to the nearest through technical actions within the constraints

(ii) a set of decision rules which results from the reasoning course

(iii) a set of adapted crop and environment observations which must accompany the set of decision rules

(iiii) a set of tools for decision rule management to make the rules operational.

Obviously, it is desirable that such a technical itinerary should be valid in a large range of constraints. At present, even the best informed farmers can only reason on the basis of not well defined mechanisms and consequently they may utilize a set of decision rules valid only for a restricted range of constraints.

So, the study aims at building a model of technical itinerary (labelled $TI_{mod}$) which is valid for a wide range of constraints representative of the Mediterranean Basin. The first step of the research is to construct a $TI_{mod}$ which is assumed to be general enough to reach the previously stated objectives in various sets of constraints under which tomatoes are grown in the Mediterranean Basin. Then, the second step is to test $TI_{mod}$ i.e. in verifying whether the intermediate and final goals have been reached. For that purpose, experiments have been planned in various locations over a three-year period. Later on, it is forecasted that the data obtained by specific observations and measurements performed on the crop and the environment data during the season will be utilized for the evaluation of $TI_{mod}$ by comparisons to a model integrating effects of various factors on the various aspects of the crop (Bussières, 1990, Bussières and Dumas, 1992), to improve modelling, to focus the intermediate objectives and to improve the set of decision rules and their management tools.

### 2.2. Precise production objectives and constraints considered in the study

The precise production objectives for $TI_{mod}$ were a yield of 70 t ha$^{-1}$ for the production of paste, a °Brix of 5.25 and a juice pH < 4.4, which can be considered as required by the industry to be competitive. The main considered constraints shared by almost all the sites were : limited water resources for irrigation and high labour costs.

### 2.3. Construction of $TI_{mod}$ : reasoning, establishing of the decision rules and of tools to manage the decision rules

The reasoning was mainly based on the current knowledge of the functioning of tomato crop or of its environment. A major part of this knowledge is the following. Dry matter content of tomato fruit and °Brix of tomato juice greatly depend on water import in fruit, providing the import of assimilate is not limiting (Ho *et al.*, 1987, Sanders *et al.*, 1989, Mitchell *et al.*, 1991, Bussières, 1993, 1994, 1995, Ho, 1996), and, therefore, they are greatly related to fruit size. So, based on previous findings (Dumas *et al.*, 1994, Dadomo *et al.*, 1994, Rodriguez del Rincon *et al.*, 1994) a strong hypothesis is that it is possible to have a °Brix of 5.25 corresponding to a mean fruit weight of 0.070 kg. In these conditions, 100 fruit/m² are necessary to reach a yield equal to 70 t $ha^{-1}$. Then, based on the available knowledge, a watering strategy can be formulated in relation to various crop stages and to the thresholds of soil moisture to aim at the target mean fruit weight and the target number of fruit.

The formulation of most of the decision rules was based on state variables of the surrounding conditions (e.g. climate parameters recorded by meteorological stations, physico-chemical characteristics of the soil) and of the vegetative cover (e.g. crop stage, pest or weed counting, disease symptom). These variables were supposed to be obtainable by growers. Thus, a standardized set of observations labelled «management observations» applied to these variables was performed. Generally the decision rules were of the form: «if a given state or value of one or several variables is observed ....., then act in a given way ...., else act in another way».

To make it easier for the application of the decision rules and to reduce the risks of reasoning errors or of rule choice, the content of some rules was or is being translated into a software. A software is also prepared to distribute the rules and the management observations over time during the crop cycle.

### 2.4. Test of the technical itinerary

#### 2.4.1. Testing methodology

The technical itinerary $TI_{mod}$ is tested by managing the crop from the set of decision rules, partly based on management observations, and the tools for rule management.

To evaluate $TI_{mod}$ more completely, a second type of tomato crop management, named $TI_{loc}$, is tested (Figure 1). $TI_{loc}$ is based on local « expertise » e.g. a professional well aware of the state-of-the-art, at the farming level, of the best growers - i.e. the growers who have well adopted the latest technical innovations- near each site. Only informations or methods utilized by these growers may be used in $TI_{loc}$ which will be different from $TI_{mod}$ because the best farmers seldom use all the best available techniques at the same time. By nature, $TI_{loc}$ is a technical itinerary including reasoning and decision rules only more or less clarified, and therefore it probably is valid only for a narrow range of constraints.

#### 2.4.2. Experimental design

Research activities take place in ten sites :
- 2 sites in France: Avignon in Provence and Réunion Island (Indian Ocean)
- 2 sites in Greece: Corivos in West Peloponnesus and Thessaloniki in Macedonia-Thrace
- 3 sites in Italy: Bologna and Parma in Emilia-Romagna, Napoli in Campania
- 1 site in Portugal: Évora in Alentejo.
- 2 sites in Spain: Pamplona in Navarra and Badajoz in Extremadura

The 10 sites differ greatly by their soil and climate and social-economic contexts.

In each site, $TI_{mod}$ and $TI_{loc}$ are performed with four replications. The plot size is at least 500 $m^2$ to allow the use of agricultural equipments and techniques. To simplify the general design and to make easier for data analysis in $TI_{mod}$, only one cultivar is utilized throughout the programme and crop installation is performed by transplanting tray-cell grown seedlings in all the sites although a different installation might have been considered in some sites.

The experiments were performed in 1997 and they will be carried on in 1998 and 1999.

#### 2.4.3. Measurements and observations performed in the plots

In each experiment, observations and measurements are performed at relevant times throughout the crop cycle (Figure 1). They are independent from the management decisions of the present crop. These observations focus on: climate (temperatures, global radiation, rainfall, air moisture, duration of moistening, wind speed by a climatic station situated near the experimental design), soil (physical and chemical state, water content), plant (progress of plant growth and development), soil volume in the root zone, evolution of pests, evolution of diseases throughout the cropping. At harvest time, yield components, fruit composition, juice characteristics are recorded. As far as possible, a standardization of the methods and of the data recording (joint Excel(RM) file) in the various sites is achieved.

## 3. Results and discussion

In the first year (1997), we mainly set up and adjusted the work. The programme was constructed in detail by the Working Group of the scientific teams in the project. A set of 103 rules and sub-rules was established for $TI_{mod}$ : 12 for crop installation, 32 for fertilization, 17 for irrigation, 14 for weed control, 12 for pest control, 11 for disease control and 5 for harvest date. Softwares have been or are being prepared to help for decision-making. For example, IRRIGERE (Battilani *et al.*, in press) is a software for crop watering, which enables a better master on the technological quality of the fruit, as well as the dynamics of the ground water (limitation of the risks of drainage). FERTILIZ will enable to run fertilizing and fertigation operations and PROTEC will help for decision-making for crop protection. MEMORULE will help for rule-set application over time from plot preparation to crop harvest.

A set of variables to be measured for management observations together with a measurement planning for crop management according to the decision rules have been established lying on physical and biological variables like soil chemical analysis, water balance, pest counting, etc.

The trials performed well in 1997. The decision rules have generally been applied and have yielded a wide range of reliable results. An important work of gathering, calibrating and processing of data has been carried out.

A general exploitation of the results from the ten sites is forecasted and new ecophysiological information collected in the study should lead to better models.

It is expected that some of the scientific considerations extracted from $TI_{loc}$ might be introduced progressively into $TI_{mod}$. Finally it is hoped that the results will improve our scientific knowledge and the ecophysiological models. Eventually, a decision-making software should be available to farmers for a better management of tomato cropping.

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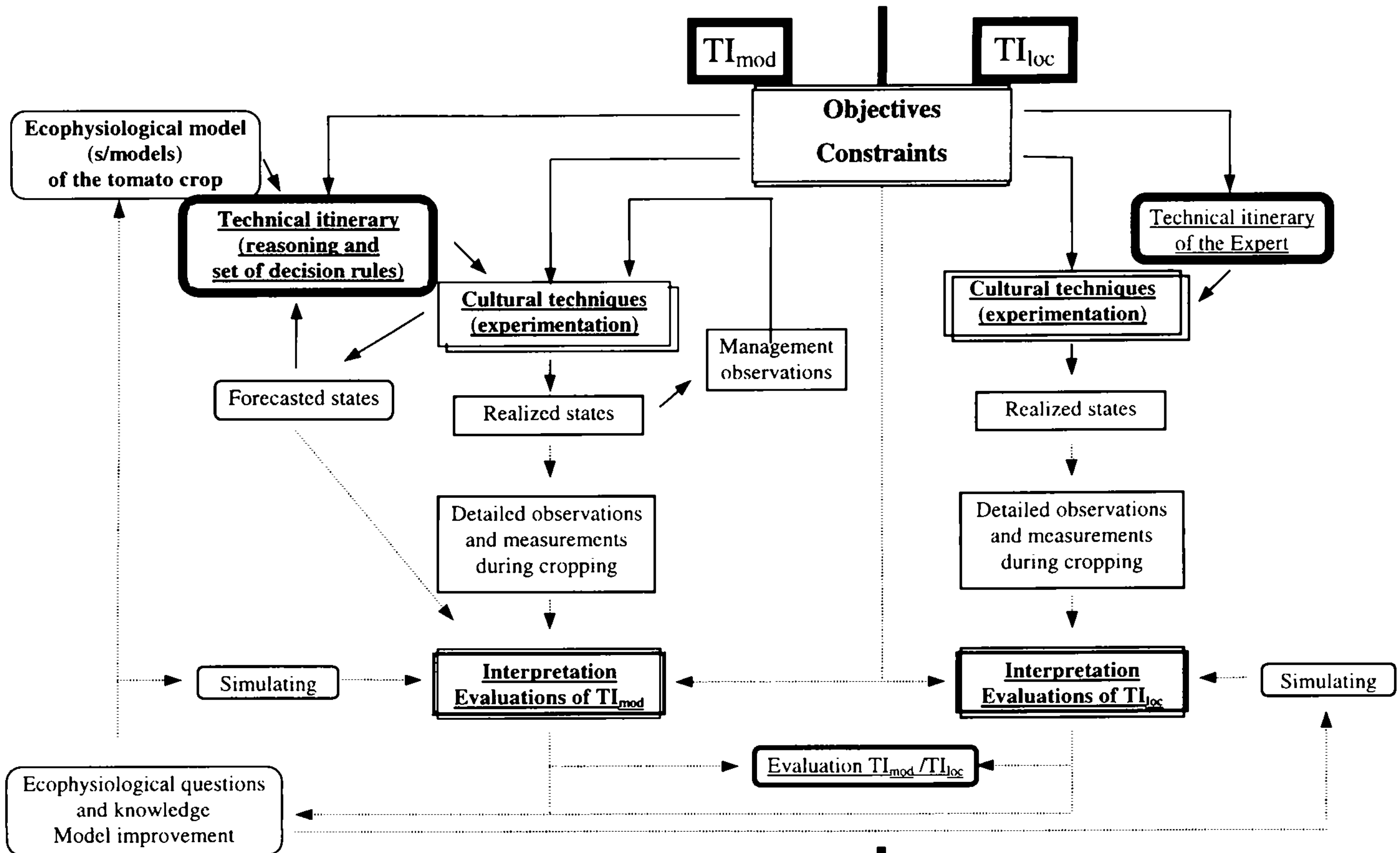


Figure 1. Scheme of the approach used in the QUALITOM programme