Processing tomatoes: fruit quality control

Y Dumas
P Bussières
P Cornillon
INRA
Unité de recherche en écophysiologie et horticulture
Domaine Saint-Paul
Site Agroparc
84914 Avignon cedex 9
France

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ABSTRACT
The range of criteria concerning the quality of industrial tomatoes is regularly widening, thus limiting the choice of crop management sequences.
The present study focused on determining cropping techniques that could be used to improve tomato fruit dry matter content.
Modelling of tomato crop fields should be useful for designing efficient crop management sequences.

La tomate d'industrie, maîtrise de la qualité du fruit.

RÉSUMÉ
Les critères de qualité de la tomate d'industrie deviennent nombreux et sont autant de contraintes pour le choix des itinéraires techniques de culture. L'amélioration de la teneur en matière sèche du fruit par les techniques culturales a été étudiée. La modélisation de la parcelle devrait permettre de mieux raisonner les itinéraires techniques.

El tomate de industria, dominio de la calidad del fruto.

RESUMEN
Los criterios de calidad del tomate de industria se vuelven numerosos y son tantos apremios para la selección de los itinerarios técnicos de cultivo. Se estudió el mejoramiento del tenor en materia seca del fruto por las técnicas culturales.
La modelización de la parcela debería permitir de razonar mejor los itinerarios técnicos.

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KEYWORDS
Tomatoes, food industry, quality, water, nitrogen, dry matter content, nutrient disponibility, water availability, models.

MOTS CLÉS
Tomate, industrie alimentaire, qualité, eau, azote, teneur en matière sèche, disponibilité d'éléments nutritifs, eau disponible, modèle.

PALABRAS CLAVES
Tomate, industria alimentaria, calidad, agua, nitrógeno, contenido en materia seca, disponibilidad de nutrientes, disponibilidad del agua, modelos.

introduction

Several agronomic research studies carried out at the Avignon (France) INRA Center concern in-soil field cropping of vegetables producing plump fruit, mainly solanaceae and cucurbits. These crops are important in the Mediterranean Basin and in southern EU countries. This research was based on complementarity between agrophysiological analysis and concerns to design efficient crop management sequences (DUMAS *et al*, 1983; DUMAS, 1992). These studies were focused especially on industrial tomato cropping, which is the topic of the present paper.

There is considerable production of industrial tomatoes in EU countries and member states of the AMITOM (Association méditerranéenne internationale de la tomate d'industrie) (table I). French production is quite small-scale but nevertheless backed by an excellent interprofessional organization and substantial research (genetics, crop protection, agronomy, technology).

Industrial tomato cropping is progressing regularly, particularly in the field of harvest mechanization, which is a constraint to crop management sequences in many ways (DUMAS and BUSSIÈRES, 1992) and raises quality concerns. Since 1991, because of new community regulations, tomato production sale prices in the EU have been set according to fruit dry matter content. Quality criteria such as colour, viscosity, taste and innocuousness, which to date were not taken into serious consideration for the tomato, are now required for new processed products. Research programs are currently designed to take quality characteristics into account.

Table I
Production of industrial tomato fruit (tonnes) between July 1991 and June 1992 (Source: *Tomato News*).

Spain	845 000
France[1]	321 000
Greece	1 129 000
Italy	3 426 000
Portugal	706 000
Subtotal for EU	**6 427 000**
Israel	168 000
Tunisia	470 000
Turkey	1 110 000
Subtotal for AMITOM member states	**8 175 000**
California	8 973 000
Other US states	888 000
Canada	500 000
Subtotal for North America	**10 361 000**
Mexico	300 000
Peru + Venezuela	140 000
Brazil	883 000
Argentina	225 000
Chile	629 000
Subtotal for Latin America	**2 177 000**
Other countries (*n* = 10)	1 500 000
Total[2]	**22 110 000**

[1] Southeast + southwest; [2] Ex-USSR and China not taken into account.

impact of water and nitrogen input on tomato quality

Between 1991 and 1994, an international research programme was created with the financial support of the Commission of the European Communities to improve the quality of industrial tomatoes in the Mediterranean region. This programme was coordinated by AMITOM and involved three complementary projects:

– project A: improvement of the technological quality (dry matter content) of industrial tomatoes through cropping techniques;
– project B: definition of quality standards for fresh fruit, according to the destination; design of harvest registration stations;
– project C: procedures for choosing new commercial varieties.

The main goal of project A, the only one presented here, is to study variation patterns for tomato soluble dry matter content, according to availability of water and mineral elements in the soil (DUMAS *et al*, 1994).

Ten organizations (institutes and universities) took part in this project in five Mediterranean countries: Spain (north and south), France (south), Greece (centre), Italy (north and south) and Portugal (south). The studies were carried out over 3 years at six geographical sites according to a common experimental procedure.

Table II
Impact of water availability on the soluble dry matter content (°brix) of ripe tomatoes (1992 harvest with the Justar or Ferry-Morse E6203 variety).

	Aliartos (Greece)	*Avignon (France)*	*Badajoz (Southern Spain)*	*Oristano (Southern Italy)*	*Pamplona (Northern Spain)*	*Parma (Northern Italy)*
i1	4.55 a	6.25 a	7.81 a	4.57 a	6.94 a	5.79 a
i2	4.28 b	4.86 b	6.84 b	4.25 b	5.98 b	5.33 b
i3	4.17 b	4.65 b	5.84 c	4.08 b	5.86 b	5.03 c

i1: ETMax x 0.5; i2: ETMax x 0.9; i3: ETMax x 1.3; with ETMax: ETP_{Penman} x cropping coefficient. In the same column, values followed by the same letter are not significantly different according to the Newman-Keuls test ($P = 0.05$).

materials and methods

Three levels of water input were applied through regular restricted rations, from the beginning of plant flowering until the fruit were half ripe:
– i1 = ETMax x 0.5;
– i2 = ETMax x 0.9;
– i3 = ETMax x 1.3, with ETMax = ETP_{Penman} x cropping coefficient.

Sprinkler irrigation conditions were kept as steady as possible.

Three levels of nitrogen input were applied at the onset of flowering: N1 = 50 kg N/ha; N2 = 150 kg N/ha; N3 = 250 kg N/ha.

A split-plot experimental design was selected with four repeats. A single variety was used for all of the second and third year experiments.

The observations and measurements were carried out during the cropping period and at harvest at coordinated times at all sites. They concerned climatic factors (rainfall, temperature, radiation, wind), soil characterization parameters (soil moisture, soil nitrate content, root depth), yield components (fruit weight and number, vegetation weight), quality features (soluble and total dry matter content, pH, acidity, sugar, colour, firmness), and fruit mineral composition (N%, P%, K%, Ca%, Mg%).

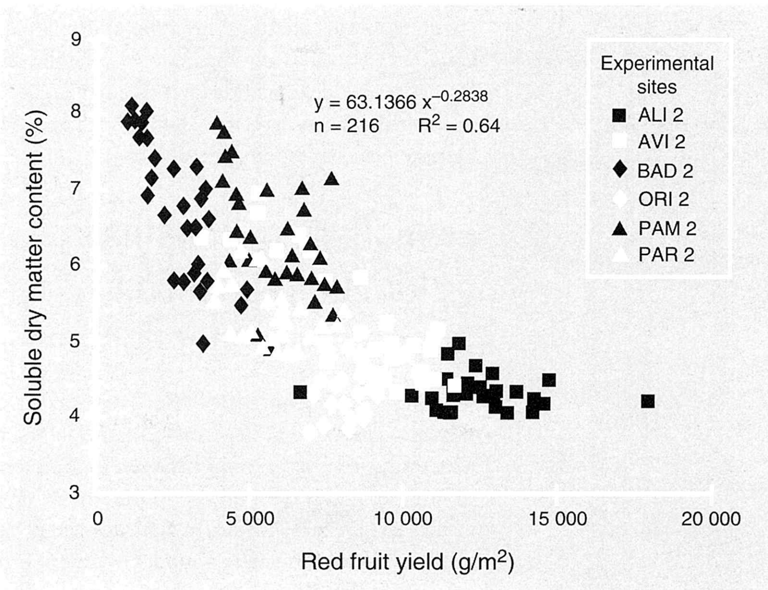
results

According to some previously published studies, water availability has an overriding positive impact on yield components, especially for red fruit (DADOMO *et al*, 1994), and on some quality features (CHRISTOU *et al*, 1994; RODRIGUEZ *et al*, 1994). In the present experiments (table II), increased water input resulted in a decrease in fruit dry matter content at all the sites considered. However, depending on the site, the variation margins and limits varied considerably. This highlights the presence of interactions between the set of environmental factors and the techniques applied.

In contrast, the different nitrogen input doses generally had little effect on most of the variables investigated.

In figure 1, the set of points relating tomato dry matter content and red fruit yields at harvest fit a hyperbolic curve, possibly indicating some compensation between yield and this quality feature. In figure 2, the points represent the relation

Figure 1
Ratio between red fruit (tomato) yield and soluble dry matter content of fruit for six experimental sites (1992 harvest).



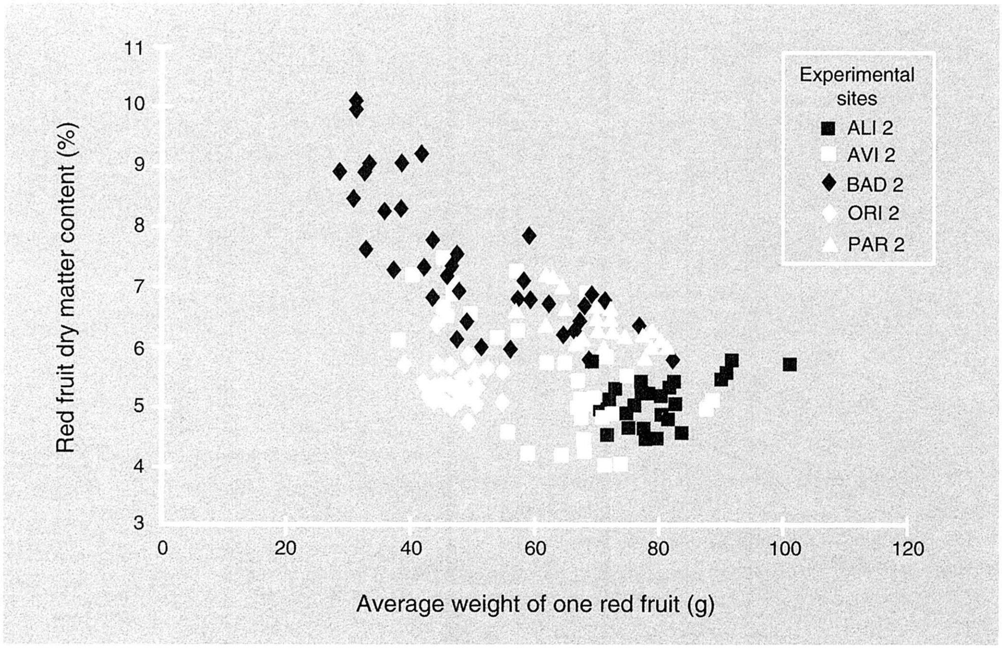


Figure 2
Ratio between the average weight of one fruit (tomato) and its dry matter content for five experimental sites (1992 harvest).

between dry matter content and mean red fruit weight; the smaller the fruit, the higher their dry matter content. Conditions favouring small fruit production would thus improve some quality features.

These network-wide experiments were conducted under very different production conditions. The results showed marked deviations in the parameter values. Substantial variability in response to the studied factors, or a wide range of changes in the relations between the analysed variables were especially apparent between the different sites. Modelling studies were then undertaken to clarify the causes of this variability and to improve management of cropping techniques.

modelling industrial tomato production and dry matter content

The dry matter content of fruit harvested in a tomato field seems to depend on many factors. It is determined by the ratio between amounts of dry matter and water built up in the fruit which, at harvest, are red and not rotten. Research has been conducted to create a model to describe all aspects concerning tomato plots so as to better understand the development of dry matter content and other important aspects, such as harvest date and yield.

The model currently being developed (BUSSIÈRES, 1990) distinguishes different levels of organization in the plot, and takes the variability present at each level into account (fig 3). For a given plant row, this model simulates variations for each plant over time and then for each plant, it details the characteristics of each truss, then of each fruit. There can be marked variability between field-grown plants, linked, for example, with differences in plant spacing (fig 4) and with climate over the time course of plant growth.

Values for different plant cover and environmental variables are simulated from relations linking them with techniques and climate (fig 5, adapted from BUSSIÈRES and DUMAS, 1992).

In developing this production model, the fruit-swelling process required special research. According to HO *et al* (1987), if assimilate availability is sufficient to not limit tomato growth, the rates of water and dry matter intake in the fruit will vary with time according to bell-shaped curves, distorted to various extents on the basis of the nutrient medium salinity. From these data, almost linear relations were highlighted (BUSSIÈRES, 1993) between fruit radius (r) and radial growth rate (F_{eau}), due to the weight of water absorbed by the fruit (fig 6).

Similar links were found for radial growth rate (F_{ms}) due to the weight of dry matter allocated to the fruit, and correlations between F_{eau} and F_{ms} were highlighted. A model was created (BUSSIÈRES, 1994a) to take these relations with the radius into account, based on the following hypothesis: water taken up by the fruit through the peduncle occurs via transfer pathways, with the water velocity respecting Darcy's law applied to water transfer in a porous environment. This model is based on a rate of water uptake by the fruit, which is a decreasing linear function of the radius, and varies with the plant water potential. These relations allow simulation of fruit growth (dry matter weight and content) at any time, as a function of fruit radius (BUSSIÈRES, 1994b). The model presented should help partially explain the variations in fruit dry matter content and weight that were noted in the different experiments carried out throughout the European test network described earlier.

The plot model accounts for variations linked with variables characterizing the row (fig 7), or inter-plant variability within the row (table III), in a few tomato plots (BUSSIÈRES, 1990). This model is still being developed and should eventually contribute to a better understanding of cropping techniques.

conclusion

Analysis of the results of the present studies, conducted in a European network, should improve the industrial tomato crop funtion model and enable its validation for a variety of conditions. One general aim will then be to develop efficient crop management sequences. From available information (published and modelling results), and on the basis of production objective/constraint concerns, schemes should be developed so that adapted techniques can be designed and scenarios simulated, and ultimate results could thus be compared to initial objectives.

Extension of the research network to climatic zones differing from those found in Europe (eg, intertropical zone), with special climate and soil characteristics, would be interesting from an agrophysiological viewpoint. Complementarity

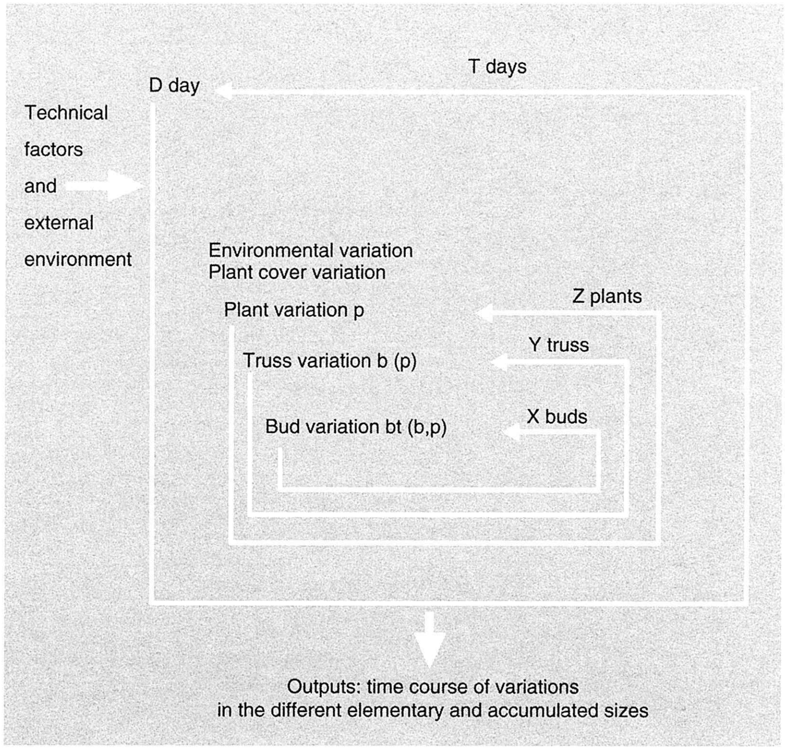


Figure 3
Diagram showing various levels of organization in a single tomato plot and their variability.

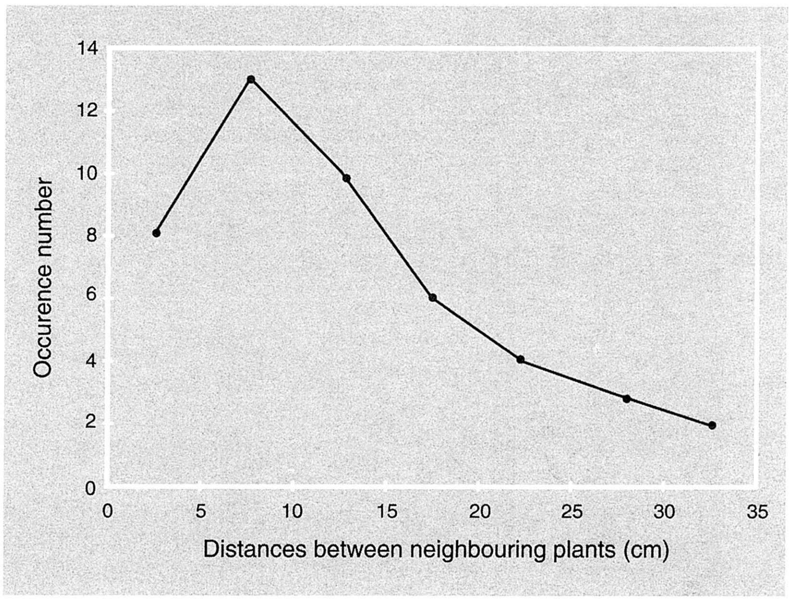


Figure 4
Variability in the spacing between tomato plants in a single row.

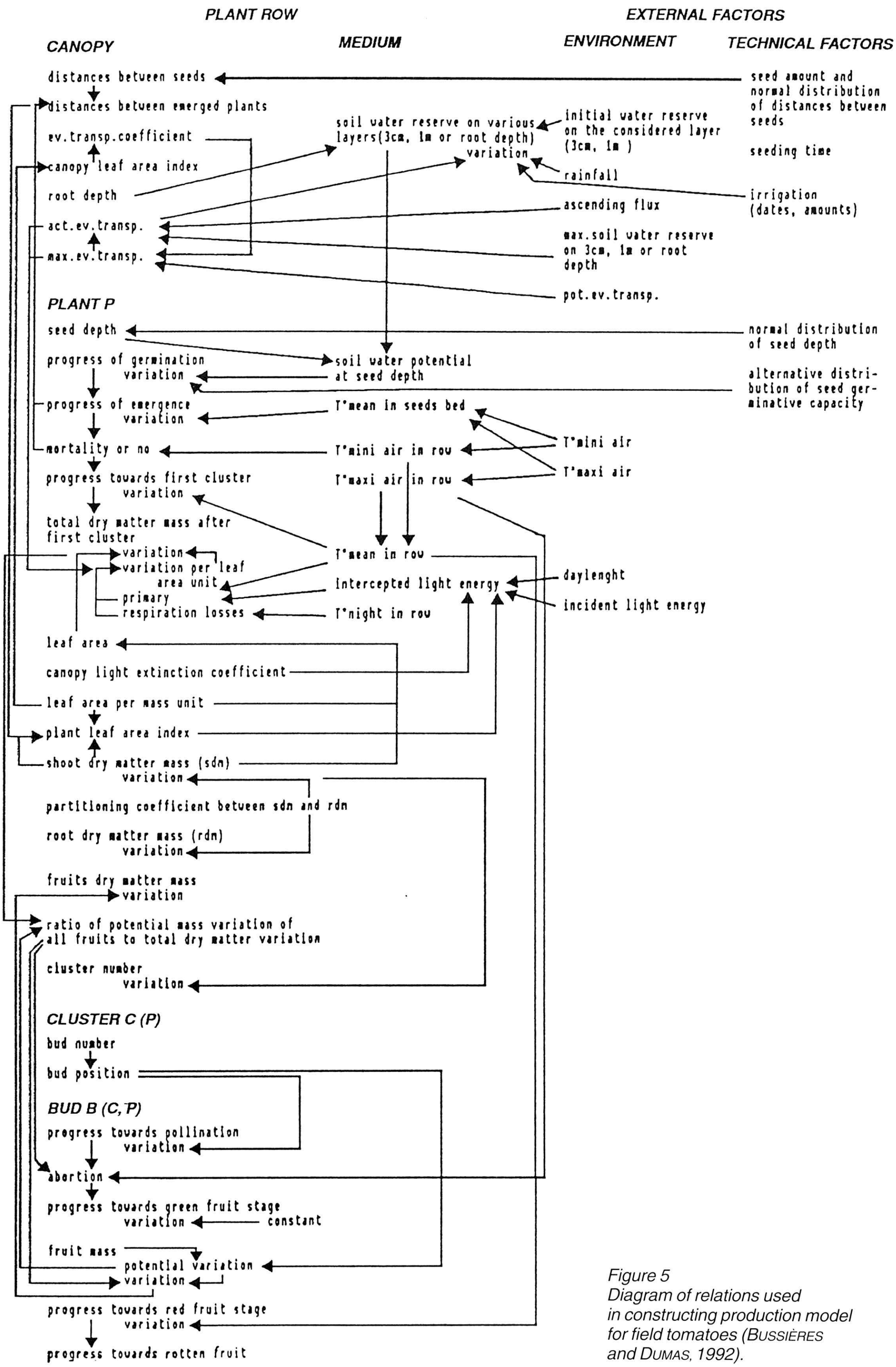


Figure 5
Diagram of relations used in constructing production model for field tomatoes (BUSSIÈRES and DUMAS, 1992).

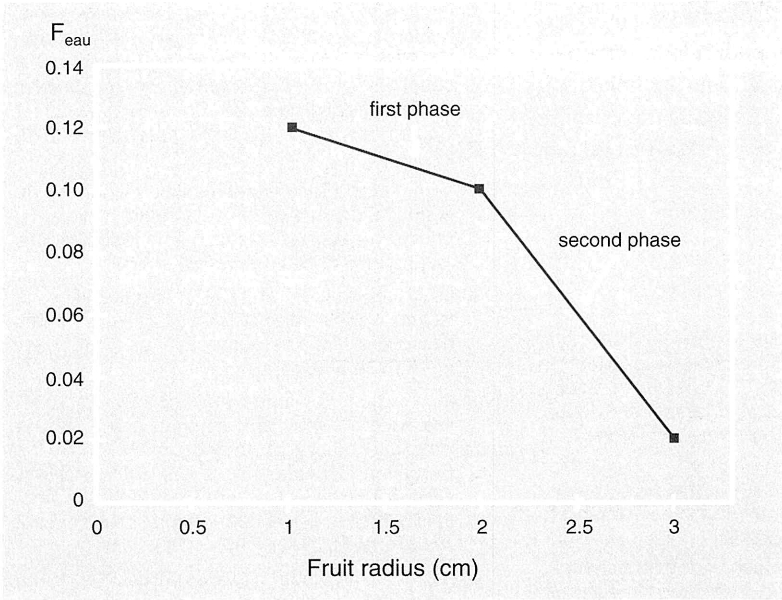


Figure 6
Scheme of variations in water radial intake rate (F_{eau}, g/cm^2/day) in tomato fruit, as a function of its radius (adapted from BUSSIÈRES, 1993).

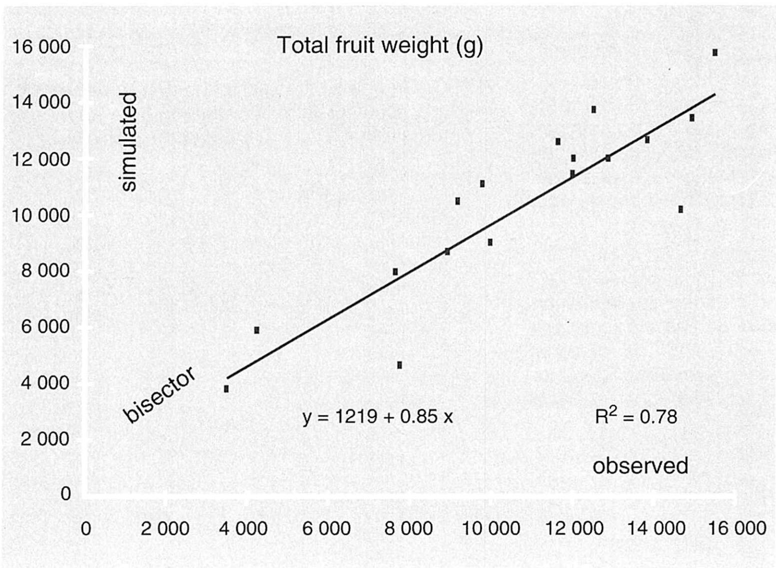


Figure 7
Comparison of observed and simulated fruit weights (green, red and rotten) in tomato rows (adapted from BUSSIÈRES, 1990).

Table III
Comparison of observed (experimental results) and theoretical (values given by the model) variability between tomato plants in a single row.

	Observation		*Simulation*	
	Mini	*Maxi*	*Mini*	*Maxi*
Weight of red and rotten fruit per plant (g)	0	1 119	75	1 327
Average weight of one fruit per plant	29	69	15	83

could be developed concerning procedures for creating crop management sequences. The results obtained could then be applied to other cropping and production systems. Within this context, it could be possible and interesting to establish cooperations with other teams also interested in tomato cropping, such as CIRAD-FLHOR teams based in Senegal and Réunion.

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