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Integrated Fruit Production—Enhancing Production, Quality, and Safety of Fruit Production and Packing of Mango in Brazil as a Model

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The development and implementation of ecosystem-based technologies in plant protection have been important objectives of the International Organization for Biological Control (IOBC) since its foundation in 1956. Integrated Production/Integrated Farming is a system that produces high quality and safe food and other products by using natural resources and regulating mechanisms to replace polluting inputs and to secure sustainable farming. The objectives and principles of Integrated Production (IP) are based in a holistic view of the system, combining strategies such as Integrated Pest Management (IPM), safety, fertilization, and agronomic measures to enhance their effectiveness. It relies on ecosystem regulation, food safety, the importance of animal welfare, and on the preservation of natural resources. The expansion of the mango growing area in Brazil depends on the generation and adaptation of production technologies, as well as on consumer market tendencies that currently require better quality fruit. Brazil needs to adjust itself to agricultural production systems like Fruit Integrated Production (FIP) that has the objective of economically producing high quality fruit obtained by ecologically safer methods, which minimizes the collateral undesirable effects of the use of pesticides, increasing environmental protection and improving human health. The FIP System in the São Francisco River Valley began in 2000, with the elaboration of an environmental diagnosis of the region followed by the monitoring of insects and diseases, training of technicians and farmers, study of the production chain, and elaboration of databases and procedures for integrated mango production. Today, the program counts on the participation of 287 mango producer farms, amounting to a monitored area of 8,780 ha. This program is based on the integration of scientists, farmers, consultants, and extension people, both from public and private institutions. Research studies are being carried out in order to generate and diffuse new technologies, products, and services that can be adapted to the situation of the Brazilian mango farmers.

KEYWORDS integrated production, fruit, best management practices, GAPs

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INTRODUCTION

The development and implementation of ecosystem-based technologies in plant protection have been important objectives of the International Organization for Biological Control (IOBC; http://www.entomology.wisc.edu/iobc/nrs.htm) since its foundation in 1956. The IOBC has become a leader in this field and in the field of environmentally sound production strategies in agriculture as a result of pioneering research and development activities of IOBC Working Groups during the last 3 decades.

The evolution from biological control concepts to Integrated Pest Management (IPM), and finally to a holistic systems approach, was certainly not accidental. On the contrary, it was a logical response to progress in developing concepts and scientific standards that have been important milestones in the history of IOBC. Following these developments, it became necessary to define clearly the IOBC's philosophy, principles, and practical rules of the systems approach, formerly called Integrated Production/Integrated Farming.

The definition of Integrated Production (IP) is a farming system that produces high quality food and other products by using natural resources and regulating mechanisms to replace polluting inputs and to secure sustainable farming. Emphasis is placed on a holistic systems approach involving the entire farm as the basic unit, on the central role of agro-ecosystems, on balanced nutrient cycles, and on the welfare of all species in animal husbandry. The components of the Integrated Production system viewed from a holistic approach are shown in Fig. 1.

The IOBC (Boller et al., 2005) defines integrated production by emphasizing "the preservation and improvement of soil fertility, of a diversified environment and the observation of ethical and social criteria are essential components. Biological, technical, and chemical methods are balanced

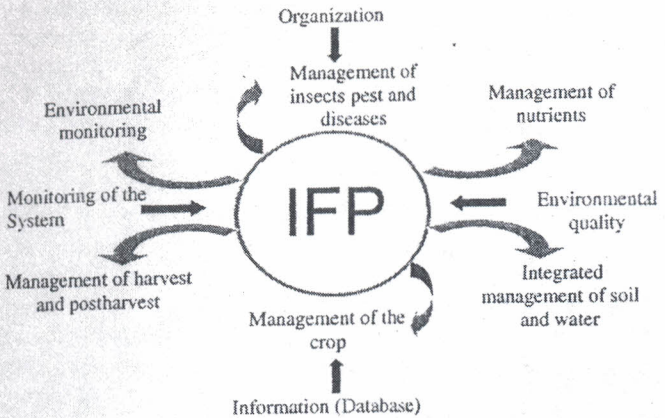

FIGURE 1 Holistic view of the Integrated Fruit Production (IFP) system.

refully taking into account the protection of the environment, profitability, nd social requirements (IOBC, 2004)."

OBJECTIVES AND PRINCIPLES OF INTEGRATED PRODUCTION

Objectives of Integrated Production

1. Integrate natural resources and regulation mechanisms into farming activities to achieve maximum replacement of off farm inputs. These objectives address the basic intentions of a sustainable agriculture. An intelligent management and careful utilization of natural resources can help to substitute for farm inputs such as fertilizers, pesticides, and fuel. Total or partial replacement of these materials not only reduces pollution but also production costs and improves farm economics.
2. Secure sustainable production of high quality food and other products through ecologically preferable and safe technologies. Integrated Production aims at high quality agricultural products mainly through ecologically sound techniques that are safe for human health. Total quality evaluation of the agricultural products considers, as significant criteria, not only their specific internal and external characteristics and food safety (produce quality), but also all sustainable methods of crop production (ecological quality), adequate standards in animal production (ethical quality), and adequate working conditions of the farm workers (social quality).
3. Sustain farm income. Farm products produced with a high level of ecologically safe, ethically sound, and socially acceptable quality must generate justified "added values." Sustainable agriculture and marketing have to apply the principle of fair trade to the largest possible extent.
4. Eliminate or reduce sources of present environmental pollution generated [illegible]. Pollution of agricultural origin has to be reduced or

5. Sustain the multiple functions of agriculture (multifunctionality). Agriculture has to meet the needs of the entire society, including those requirements that are not directly connected with the production of food and fiber. Diversified landscapes, wildlife conservation, colonization, and cultivation of remote areas, as well as maintenance of local cultural traditions are some of the nonagricultural environmental and recreational values provided by operational farms.

The Principles of Integrated Production (IP) as Defined by the IOBC (Boller et al., 2005) are:

1. "Integrated Production is applied only holistically. IP is not merely a combination of Integrated Pest Management and additional elements such as fertilizers and agronomic measures to enhance their effectiveness. Instead, it relies on ecosystem regulation, on the importance of animal welfare, and on the preservation of natural resources.
2. External costs and undesirable impacts are minimized. Detrimental side effects of agricultural activities, such as nitrate or pesticide contamination of drinking water, or erosion sediments in waterways, impose enormous costs to society. These external costs are normally not reflected in budgets for agricultural expenditure and must be reduced.
3. The entire farm is the unit of IP implementation. IP is a systems approach focusing on the entire farm as the basic unit. When practiced on isolated individual areas of the farm, IP is not compatible with a holistic approach postulated above. Important strategies, such as balanced nutrient cycles, crop rotations, and ecological infrastructures become meaningful only if considered over the entire farm.
4. The farmers' knowledge of IP must be regularly updated. The farmer plays a key role in IP systems. His or her insight, motivation, and professional capability to fulfill the requirements of modern sustainable agriculture are intimately linked to his or her professional abilities acquired and updated by regular training.
5. Stable agro-ecosystems must be maintained as key components. Agro-ecosystems are the basis for planning and realization of all farm activities, particularly those with potential ecological impact. They are the visible expressions of the holistic concepts and provide both natural resources and regulation components. Stabilization means the least possible disturbance of these resources by farm activities.
6. The nutrient cycles must be balanced and losses minimized. "Balanced" in this context means targeting maximum reduction of nutrient losses (e.g., leaching), a cautious replacement of those amounts leaving the farmed area through sales of commodities, and recycling of farm materials.
7. The intrinsic soil fertility must be preserved and improved. The intrinsic fertility of soil is the production capability of the soil without external interventions under given site conditions. Accordingly, fertility is a function of balanced physical soil characteristics, chemical performance

and balanced biological activity. The soil fauna is an important indicator of soil fertility.

8. Integrated pest management (IPM) is the basis for decision making in crop protection. Integrated Pest Management (IPM) applies to noxious species of phytophagous animals, pathogens, and weeds. Noxious species are those causing more losses than benefits. In the context of sustainable agriculture emphasis within plant protection is placed on preventive ("indirect") measures that must be utilized to the fullest extent before direct measures are applied (control). "Control" means management of the pest population to maintain it below that level that causes economic losses. Decisions about the necessity to apply control measures must rely on the most advanced tools available, such as prognostic methods and scientifically verified thresholds. The instruments of direct plant protection are the last resort if economically unacceptable losses cannot be prevented by indirect means.
9. Biological diversity must be supported. Biological diversity includes diversity at the genetic, species, and ecosystem level. It is the backbone of ecosystem stability, natural regulation factors, and landscape quality. Replacement of pesticides by factors of natural regulation cannot sufficiently be achieved without adequate biological diversity. Stable agro-ecosystems in which flora and fauna are diversified provide important ecological services to the farmer covered by the term "functional biodiversity."
10. The total product quality is an important characteristic of sustainable agriculture product quality. Quality must not only be defined by the conventional external and internal product quality parameters but also by those production, handling, and social criteria not visible to the consumers. Farm commodities produced at a high total quality level do not only exhibit high standards in conventional and measurable parameters such as external and internal quality. They also have to meet the requirements of quality traits that are not visible to consumers: namely, the quality of production (ecological quality), the quality of animal rearing, holding, transportation, and slaughtering procedures (ethical quality), and adequate working conditions of the farm workers according to the UN Charter of the International Labor Organization (social quality) (ILO, 2005).
11. Animal production on mixed farms. Animal density must be maintained at levels consistent with other principles. Animal density per ha farmland has a major impact on the nutrient balance of the farm. Purchased animal feed and animal manure have important effects on nutrient cycles, edaphic diversity, and environment."

Integrated Fruit Production (IFP) is the system of production of the future in Europe, and conventional systems will not be able to compete with it there in the near future. The target is environmentally friendly safe food, and guidelines have been under development for several years in the European Union. Different countries have had different rates of adoption, but growth has generally been dramatic, as consumers increasingly comprehend IFP and demand food produced with reduced pesticide use. Integrated Fruit Production is seen by many in the European fruit industry as a way of branding and maintaining market share for European apples in the presence of local overproduction.

Euro-guidelines have been determined for Integrated Fruit Production that specify all attributes of production, including inspection for compliance and fines payable for infractions. Guidelines cover choice of varieties for certain soil and climatic conditions, pruning systems, grass cover, nutrition, thinning, irrigation, harvest date, and plant protection. The range of acceptable chemicals is normally more restrictive than the list of registered products. As of 1995, 70% of Swiss orchards are registered as being capable of producing high quality fruit with very low residues and minimum environmental impact, and Italian orchards are moving rapidly in this direction (Suckling and Loriatti, 1995).

Integrated Fruit Production is a production system in which growers have a set of guidelines to follow. Growers monitor all aspects of the production cycle against these guidelines, and use thresholds to respond to the findings in accordance with recommended practices. The guidelines influence virtually all the management decisions within the production system, with the desired outcome of economic and environmentally sustainable production of safe food.

IMPLEMENTATION OF THE INTEGRATED FRUIT PRODUCTION TO MANGOS IN BRAZIL

Mango is one of the Brazilian fruits that has an increasing potential for export due to its competitive position in the international market for its selling price, production cost, and quality. In Brazil, the São Francisco River Valley is the main mango production region, with a cropped area of 22,000 ha. 62.8% and 25.7% of this area are in Bahia (BA) and Pernambuco (PE) states, respectively. The region of the Submedio São Francisco River Valley, where the Irrigated Agriculture Pole of Juazeiro-BA, Petrolina-PE is located, has the highest concentration of mango farms (12,500 ha) corresponding to 57.3% of the total planted area of the whole valley (CODEVASF, 1999).

In spite of this potential and the economic importance of mango fruit for the national and international markets, the crop has not yet achieved desirable export levels, mainly due to fruit quality deficiencies for the international market. This situation is common in the São Francisco River Valley,

due to climatic conditions and irrigation use, it has production potential for the whole year, and the ability to supply the international market in seasons that competitors cannot offer the product. The actual world fruit market potential is higher than US$20 billion per year, and the access to this market depends on a great and complex number of factors that, besides the traditional no-tariff barrier, correspond to quality and competitive requirements of the importing markets of Europe, the United States, Asia, and Mercosul.

Economic changes that occurred in the last decade, like the increasing world economy, the opening of market establishments and their unification in regional blocks, and competition increases on global levels have determined that companies look for and maintain high levels of competitiveness. This competitiveness, which is linked to the maintenance and enlargement of markets, is affected by a set of factors that act in the productive unit and by the world economy stability. So, developed countries adopted Integrated Fruit Production (IFP).

IFP is a cropping system that produces food and other high quality products by using natural resources, adequate technologies, and rule mechanisms to minimize the use of chemicals, assuring a sustainable production with competitive prices, preserving the environment. Conservation and improvement of soil fertility and environment diversity are very important in the agricultural production system. Biological, chemical, and technical methods are used in a balanced way that harmonizes production, environment, profitability, and social demand (Titi et al., 1995).

Establishment of the Mango Integrated Production Program

The Mango Integrated Production Program began in the São Francisco River Valley in 2000, through an agreement set up by VALEXPORT (Fruit and Vegetable Producers and Exporters Association of the São Francisco River Valley), Embrapa Semi-Árido, and Embrapa Meio Ambiente to help farmers meet the demands of the of European market that would set some restrictions for importing mangoes. At the end of 2000, financial support for the establishment of research projects for the integrated production of apple, grape, papaya, peach, banana, and citrus was made available through an agreement set up by the Ministry of Agriculture (MAPA) and the National Council for Scientific and Technological Development (CNPq).

In the establishment of the mango Integrated Production System (IP), the following phases were considered.

Selection of producing areas

In the beginning of the program, seven mango exporting companies associated with VALEXPORTwere selected. Later, other companies were voluntarily

incorporated, and in Aug. 2002 there were 287 companies, with 1,065 surveying plots, comprising an area of 8,780 ha. The program, which aims to improve fruit quality to help assure its acceptance in national and international markets, accepts new companies that want to improve their production system.

Identification and selection of plots

In order to survey the mango production chain, collect information in the field, and maintain updated data for orchard practices, it is necessary to define the plot where all the production process phases will be registered according to agricultural cycles and the technical procedures to be adopted. The plot is defined as the production unit with only one variety and plants of the same age, under the same cropping management recommended by the IP. Recently, the plots have been numbered, geo-referenced, and mapped.

Environmental diagnosis of plots

The environmental diagnosis considered socioeconomical and environmental aspects of the region. Many thematic maps were drawn in order to classify the watersheds according to different soil uses and natural resource characteristics (vegetation, soil, climate, and water). The environment survey was done at plot scale, and the productive units were characterized in terms of the production chain, taking into account varieties, plant spacing and age, cropped area, crop management, productivity, and harvest timing. Data on drainage, irrigation systems, source, and management of water were also surveyed. Soils of the productive units were analyzed for physical and chemical characteristics and heavy metal traces to determine the vulnerability of surface and underground water to be contaminated by agro-chemicals used in the traditional cropping system. Products applied to the productive units were identified and classified according to the active principle, chemical group, validity period, product action, formulation, toxicological class, availability of methodology for residue identification, and residue maximum limit (RML) allowed in Brazil, United States, European Union, Japan and Codex (Pessoa et. al., 2001; Silva et al., 2000).

Field and postharvest notebooks

Field and postharvest notebooks are tools that inform the mango producer how to register all the information and crop management activities in the production unit plot, based on the specific technical rule recommendations. In these notebooks, the following information is registered: company

characteristic, technical manager, variety, fertilizer, irrigation, pest and disease monitoring, chemical products used, crop management, plant regulators, harvest and postharvest, the reason why the mango producer uses a specific disease control or fertilizer, as well as the criteria and objectives for that decision. The information, noted down daily by the technical manager, is the proof that the mango producer is following the established rules, assuring him receipt of a quality stamp for the fruit produced.

Mango Integrated Pest Management—MIPM

In the Mango Integrated Production System, the MIPM represents 80% of the establishing strategy for this new agricultural production technology. MIPM states that pest control has to be done through feasible techniques that aim to maintain insect populations below economic damage levels (Botton, 2001). Knowledge of mango tree pests and diseases, as well as their habits, damages, symptoms, and incidence time is very important for the efficiency of the control. In this context, the base for any MIPM system is monitoring. Main pest and disease monitoring, as well as the occurrence of natural enemies, has been done by sampling methods that involves a knowledge of crop phenology, experimental design, number of plants sampled per area in the productive unit, frequency, plant part sampled (trunk, leaves, buds, flowers, branches, and fruits), damage levels, knowledge of pests and disease epidemiology, and the climatic situation. A sampling methodology for pest, disease, and natural enemies, and a registering table were developed by Embrapa Semi-Arid (Barbosa et al., 2000a, 2000b, 2001). Handbooks for pest and disease monitoring were prepared to orient mango producers on how to identify insect and disease pest damage, symptoms in the field, and also action levels for chemical control.

Adoption of pest and disease monitoring by the companies that adopt the IP of mango allowed a significant decrease in agro-chemical application numbers that corresponded to a reduction in the use of approximately 72% of insecticides and 73% in disease control application.

Human Resource Training on Integrated Production System Monitoring

Continuous training of managers, mango producers, laborers, and students on pest and disease monitoring and how to fill in the field and postharvest notebooks is very important for the success of the program. Training is accomplished by lectures, theoretical and practical courses, technical visits, distribution of technical bulletins and other publications that emphasize the identification of symptoms and damage in the field, how to fill in the information

in crop management. The success of the program depends on the continuous dissemination of information about new technologies generated by research activities and the effective participation of the mango producers involved.

Elaboration of Specific Technical Rules

The rules for the IP of mango are based on the General Rules for Integrated Fruit Production of the Ministry of Agriculture(MAPA) (MAPA, 2001a, 2001b). A voluntary management committee responsible for planning and defining research and administration activities was formed in order to support the organizational structure for the Mango Integrated Production Project. The committee is composed by representatives of private companies, research institutions, and mango producer associations. A technical committee, composed of representatives of research institutions, mango producers, and consultants, was also established to elaborate technical norms for the IP of mango.

The norms establish criteria related to obligatory procedures that are either recommended, allowed with restrictions, or prohibited for each one of the thematic areas. Examples might include propagation material (seeds and seedlings), implementation of orchard establishment and culture (location, rootstock, variety and cropping system), soil management (soil covering and herbicides), plant nutrition, plant upper part management, irrigation, pest and disease integrated control, crop management, harvest and postharvest practices.

Mango producers that participate in the IP of mango are supervised and will be inspected periodically. Inspections will be done by enterprises registered in the national certification organization. Norm adoption by the mango producers and the registration of control and postharvest information in the field and postharvest notebooks are the basic procedures that will confirm the real use of the IP of mango. The objective of this procedure is to verify if these products conform to the norms and the actual technical regulation, because its conformity is the guarantee for the health and safety of the consumers (Inmetro, 2002).

The period of validity and revocation of the authorization to use the mark of IP of mango is also preestablished at the admission of the producer to the system; it can be revoked or suspended if nonconformities to the norms are detected by the predictor inspections.

So, for the mango producer to be admitted, stay, and be authorized to practice IP of mango, he or she must fulfill the following conditions:

- Assume technical responsibilities for producing and controlling, according to integrated production context;
- Participate in official courses on integrated production or be a member of

- Register in field and postharvest notebooks all cropping, management, and control activities, making them available to official inspectors whenever necessary.

System certification

Certification is defined by the Brazilian Technical Norm Association (Associação Brasileira de Normas Técnicas-ABNT) as a set of activities developed by an independent institution aiming to supply public proof that certain products, processes, or services are in conformity with the specific requirements. Requirements might be national or international (ABNT, 2002).

In IFP, certification must be done for the product as well as for the production process. Certification is a differentiator element for the product in the market, facilitating its identification and assuring guarantees for the product user, consequently enlarging sale opportunities for new markets. The process must be impartial, transparent, and objective, allowing the certified companies to contest any nonconformity situation related to the certifying institution (Avilla, 2000).

The easy identification of certification stamp by the consumer adds a new market value to the product in relation to safety and choice of similar products.

In Brazil, fruit certification is a new experience. The National Institute for Measures, Norms and Industrial Quality (Instituto Nacional de Metrologia, Normatização e Qualidade Industrial-INMETRO), in agreement with MAPA and private companies, developed a program to officially certify the Integrated Fruit Production program. The profile for the certifying institution will be established in order to attend to all the necessary predefined requirements. The program includes all the fruit producers interested in IPF.

CONCLUSIONS

All fruit producing countries in the world are paying attention to international rules with respect to food safety and traceability. As in Europe, some countries are implementing the Integrated Production system. In a highly competitive market, Brazilian fruit exporters must offer a good quality product that takes into account all consumer requirements. So, the IP of mango represents a set of techniques directed to the production of better quality food, mainly with very low levels of agro-chemical residues and a minimum of environmental impact from the production system.

In this context, the implementation of the Mango Integrated Production Program is based on the integration of researchers, mango producers, consultants, and public and private professionals. To support the technical

technologies, products, and services that will increase the productivity and quality—and consequently, the competitiveness—of the products in national and international markets. The great challenge is making these techniques more efficient to minimize production system effects on the environment, and to attend to markets that are more and more demanding.

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LITERATURE CITED

ABNT. 2002. Certificação. Available at http://www.abnt.org.br/certif_body.htm. May 27, 2009

Avilla, J. 2000. Sistemas de inspección y de certificación de producción integrada de frutas. In 2nd Seminário Brasileiro de Produção Integrada de Frutas, p. 9–13. Anais, Bento Gonçalves, RS.

Barbosa, F.R., F.N.P Haji, J.A. de Alencar, A.N. Moreira, S.C.C.H. Tavares, M.F. Lima, and W.A. Moreira. 2000b. Monitoramento de pragas e doenças na cultura da mangueira. Embrapa Semi-Árido, Documentos 150, p. 10–15.

Barbosa, F.R., A.N. Moreira, J.A. de Alencar, and F.N.P. Haji. 2001. Monitoramento de pragas na cultura da mangueira. Embrapa Semi-Árido, Documentos 159. p. 4–5.

Barbosa, F.R., A.N. Moreira, J.A. de Alencar, F.N.P. Haji, and V.D. Medina. 2000a. Metodologia de amostragem e nível de ação para as principais pragas da mangueira no Vale do São Francisco. Embrapa Semi-Árido, Circular Técnica. 50:24.

Boller, E.F., J. Avilla, E. Jörg, C. Malavolta, F. Wijnands, and P. Esbjerg. 2004. Integrated Production: Principles and Technical Guidelines, 3rd ed. 50 pp. International Organization for Biological and Integrated Control of Noxious Animals and Plants, IOBC WPRS Bull. Vol. 27(2). pp. 1–12.

Botton, M. 2001. Monitoramento e manejo. Cultivar. Hortaliças e Frutas. 1(6):18–20.

CODEVASF. 1999. Cadastro frutícola do Vale do São Francisco. Companhia de Desenvolvimento dos Vales do São Francisco e do Parnaíba. Brasilia. (More information available from http://www.codevasf.gov.br/).

ILO. 2005. Rules of the Game. A Brief Introduction to International Labor Standards. ILO Publications, Geneva, Switzerland. http://www.ilo.org/wcmsp5/groups/public/—ed_norm/—normes/documents/publication/wcms_084165.pdf. Accesed May 26, 2009.

Inmetro. 2005. Desenvolvimento e conquistas da Produção Integrada de Frutas no Brasil. http://www.inmetro.gov.br. Accessed May 26, 2009.

MAPA. 2001a. Definições e conceitos para os efeitos da produção integrada de frutas. Diário Oficial [da] República Federativa do Brasil, 237: 47–49. Seção 1.

MAPA. 2001b. Instruções e normas técnicas gerais para a produção integrada de frutas.

Pessoa, M. C. P. Y., A. de Silva, S. Ferracini, V.L. Chaim, L.A.N. de Sá, C.M.M. de Silva, L.C. Hermes, and G.S. Rodrigues. 2001. Impacto ambiental em fruteiras irrigadas do Submédio São Francisco – subsídios para a produção integrada da região. In 3rd Seminário Brasileiro de Produção Integrada de Frutas, p. 62–68. Anais, Bento Gonçalves, RS.

de Silva, A., M. C. P. Y. Pessoa, V. L. Ferracini, and C. M. M. da Silva. 2000. Bases técnicas e organização da produção integrada. In 6th Seminário Internacional de Citros: Produção Integrada, p. 1–35. Anais, Bebedouro, SP.

Suckling, D.M. and C. loriatti. 1995. Integrated Fruit Production: The New European Standard for Apples. The Orchardist. 68(8):48.

Titi, A. el, E. F. Boller, and J. P. Gendrier. 1995. Producción integrada: Pincipios y directrices técnicas. IOBC/WPRS Bul. 18(1):1–22.