Priority 2: Qualitative and quantitative enhancement of crop products

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Priority 2:
Qualitative and quantitative enhancement of crop products

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Abstract

The world's human population will reach rather over 9 billion by 2050, placing considerable strains on agricultural production, which depends largely on smallholder farmers. Although food production in aggregate is enough to feed the current population of about 7.1 billion, the existence of around 870 million people who are undernourished demonstrates that, on its own, it is not sufficient to ensure food security for all. Two reasons for this are that about one third of food is wasted and one third is fed to livestock (Tscharntke et al., 2012). Other drivers of food insecurity are lack of entitlement and poor access to markets. However, in this paper we will focus on constraints to quantitative and qualitative enhancement of crop production. Quantitative constraints include pests, diseases and inappropriate farm management practices: qualitative constraints include contamination of food, for example, by mycotoxins. The paper concludes with suggestions for the safe and sustainable use of resources for the increased production of high quality food.

I – Introduction

Food producers and their family members represent 75% of the global food insecure. Ensuring adequate productive capacity in short and medium term, safeguarding the surrounding environment and guaranteeing suitable markets and remunerable prices, are three fundamental prerequisites to concur to their livelihood. Food security is primarily achieved through the improvement of food vulnerable people living conditions as well as their empowerment vis-à-vis their socioeconomic context. Improving quantitative and qualitative farm production is thus strategic to achieve such farmers' livelihood renaissance, further enabling the flow of sufficient amount of food in consumption circuits.

The farming sector and farmers themselves are facing current and emerging threats: widespread economic recession and pauperisation, rural-urban disconnections, increasing resource scarcity and competition, price volatility, input market oligopolies and cartels. Peak of oil cost, climate crisis and pest vagaries pose additional pressure on productive systems and urge to restore or build resilient farming conditions.

Threats and constantly evolving socioeconomic and environmental circumstances demand new adaptative knowledge and a transition path to a more socially fair and environmental sustainable primary sector. Part of the needed knowledge is already available at scientific and community level and requires to be disseminated, accessed and adjusted to specific local contexts. Additional new knowledge is further vital: research centres and farm innovative practices concur to its provision generating innovation and new combinations of existing one.

As indicated by IAASTD and a recent EU SCAR report, a fundamental change in research policies and priorities is needed for a shift toward sustainable food systems. These prerequisites are aimed at:

– Restoring and strengthening of extension services to assist and qualify farm activities;

– Assessing, with participatory approaches, research and innovation needs, further to identifying suitable existing knowledge and know-how;

– Providing an enabling environment for sustainable food provision, through both the adoption of agroecological practices and approaches and the fulfilment of multifunctional scopes for the primary activity capable to adapt to local agroecosystem constraints and potentials;

– Enhancing ecosystem services through diversification at all levels (intra and extra- specific; spatial and sequential crop rotation; mixed farming with the reconnection of crop and livestock production at farm or territorial scale; creation, maintenance and organisation of functional biodiversity; closure of biomass and energy cycles):

– Rebuilding circular metabolisms mimicking nature cycles (i.e. for water, N, C, residues) that can help to minimize waste and to value it as functionally recycled biomass;

– Recovering soil fertility as a milestone for sustainable food production, further reducing dependence from off-farm inputs (as well as connected risk and costs) and minimizing pollution;

– Reshaping farming systems in order to adapt to and mitigate climate change, progressively emancipating food production from fossil energy;

– Adapting to local conditions and local farmers' skills while intensifying local and scientific knowledge;

– Fostering crucial resilience of agroecosystems.

Most of these far-reaching changes can occur simultaneously and be mutually supportive.

Food security is achieved when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO 1996). However, increasing population and consumption are placing extraordinary demands on agriculture and natural resources. The State of Food Insecurity in the World 2012 (SOFI), jointly published by the Food and Agriculture Organization (FAO) of the United Nations, the International Fund for Agricultural Development (IFAD) and the World Food Programme (WFP), reveals that almost 870 million people, or nearly one in eight, are suffering from chronic malnutrition. The report used innovative methodology which assessed some parameters such as food supply, food losses and dietary energy requirements more accurately than those used previously. In spite of this, it is not yet possible to assess precisely the short-term effects of food price surges and other economic shocks. Also, additional sets of indicators are needed to better capture dietary quality and other dimensions of food security. It is evident therefore that an effective response to the demand for food by all people at all times has not yet been found and that meeting the challenges of 'Food security' and 'Food safety' beyond the paradigm of crop production (which, being strictly oriented on yield, may increase food security problems), is necessary (Giovannucci *et al.*, 2012). Meanwhile our capacity to feed the world's increasing population is being thwarted by land degradation, diminishing water supplies, decreasing biodiversity and climate change.

Integrated crop management (ICM), integrated pest management (IPM), Organic farming entails the use of sustainable practices of productions that may act together to bridge the gap between ecology and agronomy, allowing the development of an ecosystem approach which will enhance yield, quality, sustainability and equity (FAO, 2010). The pillars of sustainable production are the maintainance or the enhancement of productivity and services, the reduction of the level of production risk, the protection of natural resources ant of their potential, the economical viability and social acceptability. Within this context, production of healthy food must be ensured 'always and absolutely' with regard to nutrition and organoleptic properties, and to meeting consumers' needs and expectations. Such improvements imply the responsible management of both natural resources e.g. maintenance of the long-term fertility of the soil (Powlson *et al.*, 2011), and human resources. The latter includes such social responsibilities as attention to the living conditions of workers, the needs of rural communities, consumer health and safety and the creation of new market opportunities for farmers and exporters in developing countries.

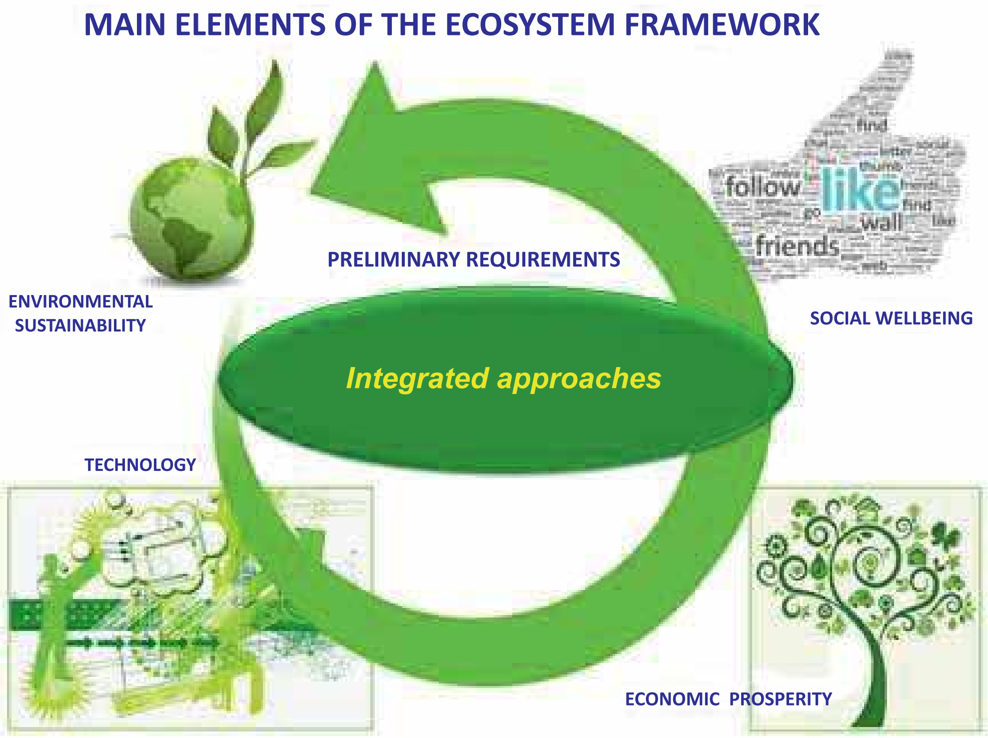

Figure 1. Graphic description of the main elements of the ecosystem framework.

II – State of the art

Increasing food availability is the first, but not the only, step towards achieving food security as, although the current global food production would seem, in aggregate, sufficient to meet energy and protein requirements of the entire population of the planet (ICROFS, 2009), about 870 million inhabitants (most of them in Africa and Asia) still suffer from hunger. Food availability, adequate access to the resources needed to produce or obtain food, a balanced diet consisting of safe food and the stability of such conditions over time, are the four key points of food security. Many studies confirm that the hunger crisis is linked to problems in food distribution (Boucher *et al.*, 1999). The current situation of yield and quality of crop grown products varies considerably depending on intrinsic factors (temperature, humidity, type of crop) and logistical factors (management, technological facilities, performance of the economy). One of the first studies addressing the problem of food losses in an analytical way was that made by the FAO in 1977 (Special Action Program for the Prevention of Food Losses) in response to a UN request. Reliable assessments of the nature and quantity of the loss of food are still rather scarce. This is due to the difficulty in collecting comparable data in different areas of the planet. Moreover, losses are usually valued for staple food grains, whereas, for an accurate assessment of food losses, those for more perishable foods, such as fruit and vegetables, should be also taken into account.

In developing countries, losses range from 5 to 50% and occur mainly in production, harvesting, storage and processing, whereas in industrialized countries losses range from 2 to 20% and are concentrated mainly in retail and final consumption (Prusky, 2011). Most of the food losses in developed countries is due to two factors: the existence of strict quality control and the demand for perfect looking food, causing the discard of perfectly edible foodstuffs.

Improvement of availability and access to food must be sustainable in economic and ethical terms. To date, increases in productivity have been through selection and breeding of high yielding cultivars such as the short-strawed wheats of the Green Revolution. Besides their favourable harvest index, a critical property of these cultivars was their resistance to stem rust. Disease and pest resistance are important properties for new cultivars but often these have to be supplemented by pesticide application. One reason for this is that pathogens and pests evolve to overcome the resistance of plants. Post-harvest, the management of temperature and humidity represents a very effective mean for the protection of food quality. Unfortunately it is very expensive to manage these two parameters in a suitable manner to ensure an effective control of foodstuffs contamination because large amounts of energy and high levels of infrastructure are required. They are therefore often not feasible in developing countries where the ambient conditions of both temperature and humidity may be high.

In addition to the problems of the evolution of resistance among pests and pathogens to pesticides, there are concerns that these products can be toxic to sector operators and their residues can accumulate in crops. This has led to special attention being paid to Organic Farming (EC 834/07, 889/08) which is aimed at minimizing the input of synthetic chemicals by the use of biological control as well as reducing overall off-farm inputs, creating microhabitats for agro-biodiversity and optimizing ecological niches for beneficial organisms that compete with harmful ones. This strategy promotes conservation and sustainability in a way that is claimed to be equitable for rural communities and small holders.

Unfortunately, when transferred to commercial reality, exclusive dependence on biological control has not been as successful as hoped. However, combining antagonistic microorganisms with pesticides has shown more promise. With regard to post-harvest storage, physical means, such as the use of modified atmospheres, have been successful as they inhibit the growth of strictly aerobic spoilage bacteria and moulds, although they have limited efficacy in the control of microaerophilic fungi.

From these observations it is evident that the use of a single technology often does not achieve the objective of efficient control of plant disease, whereas an integrated approach, combining several different methods, offers greater possibilities (Thomas, 1999). Furthermore it is clear that the preservation of the quality of foodstuffs from contamination should be carried out specifically for each category of product under the environmental conditions in which it must be preserved. In these scenarios it is evident that knowledge of the most appropriate strategies is of fundamental importance. The current lack of dissemination of knowledge of these strategies is therefore a significant obstacle to the realization of effective policies for safeguarding the quantity and quality of crop grown products.

III – Regulatory framework

In the EU the quality of agricultural products is regulated by several Directives: EC N. 2000/29/EC for preventing the introduction of pests not present on the territory of the European Community; EC N. 2003/2003 for the use of fertilizers; EC N. 396/2005 with the amending EC N. 839/2008 for the maximum residue levels of pesticides; EC N. 1881/2006 and EC N. 1333/2008 for the maximum levels of certain contaminants in foodstuffs; EC N. 834/2007 and EC N. 889/2008 governing organic production methods and the national guidelines for integrated production; EC N. 1107/2009 for placing plant protection products on the market; and EC N. 128/2009/EC on the sustainable use of plant protection products. This last directive, which regulates the mandatory use of IPM in agricultural production by 2014, will change the agriculture scenario in Europe because the use of chemicals will have to be reduced or adjusted to needs-based pesticide doses and alternative methods, where practicable, will have to be used instead.

IV – Problem Analysis in Mediterranean Region: from constraints to solutions

The demand for food is not only driven by a growing population but also by diet choice, lifestyle and food safety regulations, the last three often encouraged by media and social networks (Spiertz, 2012). To ensure the availability of food in areas where people still suffer from hunger, it is necessary to provide an increase in production specifically in those areas or as close as possible to them.

There is considerable potential for doing this by employing appropriate techniques both at the pre-harvest and the post-harvest stages, but this must be done taking into account the different socio-economic conditions prevailing in the different localities of the world. Also, it is imperative that it is done while maintaining or even increasing the fertility of the soil (Powlson *et al.*, 2011).

Pre-harvest, crop production must be enhanced while reducing the inefficient use of land, water, nutrients and living resources. To this end, the ecological intensification pattern, as represented diagrammatically in Figure 2, could be investigated as a way of increasing productivity, preserving yield and using natural resource more efficiently. Here, global food security goals are represented by the green areas. Conventional intensification is envisaged as moving the current situation (2a) towards greater environmental impacts, which are likely to be negative, while still not fulfilling global needs (2c). In contrast, ecological intensification is envisaged as moving the current situation to the left and upwards into the green safe area where the environmental impact is reduced and global needs are satisfied (2b) (Bommarco *et al.*, 2012).

A further factor is the necessity of slowing the rate of increase of the agricultural environmental footprint (Foley *et al.*, 2011). All this implies sustainable integrated management, which is a knowledge-based approach, requiring good understanding of agro-ecological processes. Access to knowledge is the major bottleneck when moving to sustainable management. Inexperience and lack of adequate extension and training for knowledge-intensive management systems and location-specific science require long-term investments in capacity building (Scialabba, 2007). Sustainable management, particularly when programmed on a large scale, cannot be conducted through the use of a single technology but should be based on the integrated use of different actions both pre- and post-harvest.

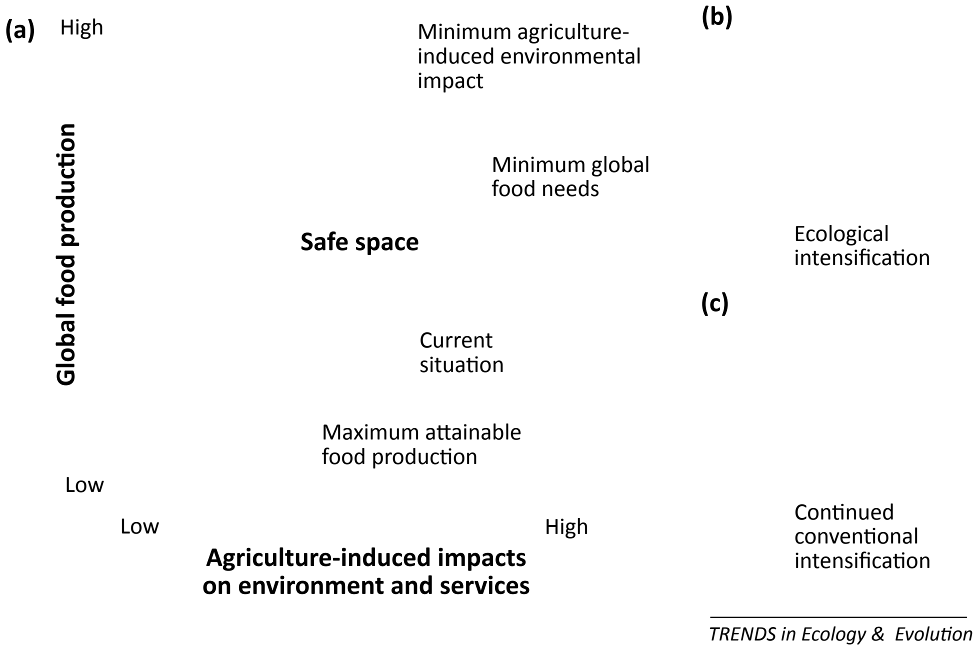

Figure 2. Ecological intensification paradigm should be considered as alternative to the yield paradigm (Bommarco *et al.*, 2012).

1. Pre-harvest

Yield increases per unit of land imply the introduction of high-yielding cultivars, well adapted to local environmental condition and resistant to pests and diseases. They should be farmed using the best practices which, in some cases, will mean the establishment of efficient irrigation technology. The main biotic and abiotic factors implicated in yield decline of crops grown in short rotation or monoculture are reported in figure 3. Detrimental effects are caused by the repeated planting of the same crop, with recurring use of the same management practices, resulting in poor plant growth and development, delayed crop production and reduced yields And also in increased contaminations (bacteria, pests, fungi) that, in turn, can lead to toxic metabolites production. Although one factor may be responsible for yield decline, it is more likely that combinations of factors interact to cause the effect (Bennett *et al.*, 2012).

2. Post-harvest

The quality of produce achieved at harvest time should be maintained from field to table. This implies storage under conditions in which neither abiotic nor biotic factors cause deterioration. Inappropriate temperature and humidity play major roles in causing quantitative and qualitative losses, while, among the biotic factors, contamination by pests and microorganisms represent the main problem. Moreover, if the contaminant produces toxic metabolites, the problem is not only the visible alteration of the commodity, but also the invisible presence of these noxious metabolites. For example, it is claimed that mycotoxins contaminate 25% of food with major negative consequences for human health (Kolosova and Stroka, 2012). Stringent quality criteria should always be applied to products in order to protect consumers in all countries. The production of high quality products, in fact, constitutes an objective which cannot be separated from obtaining good yields.

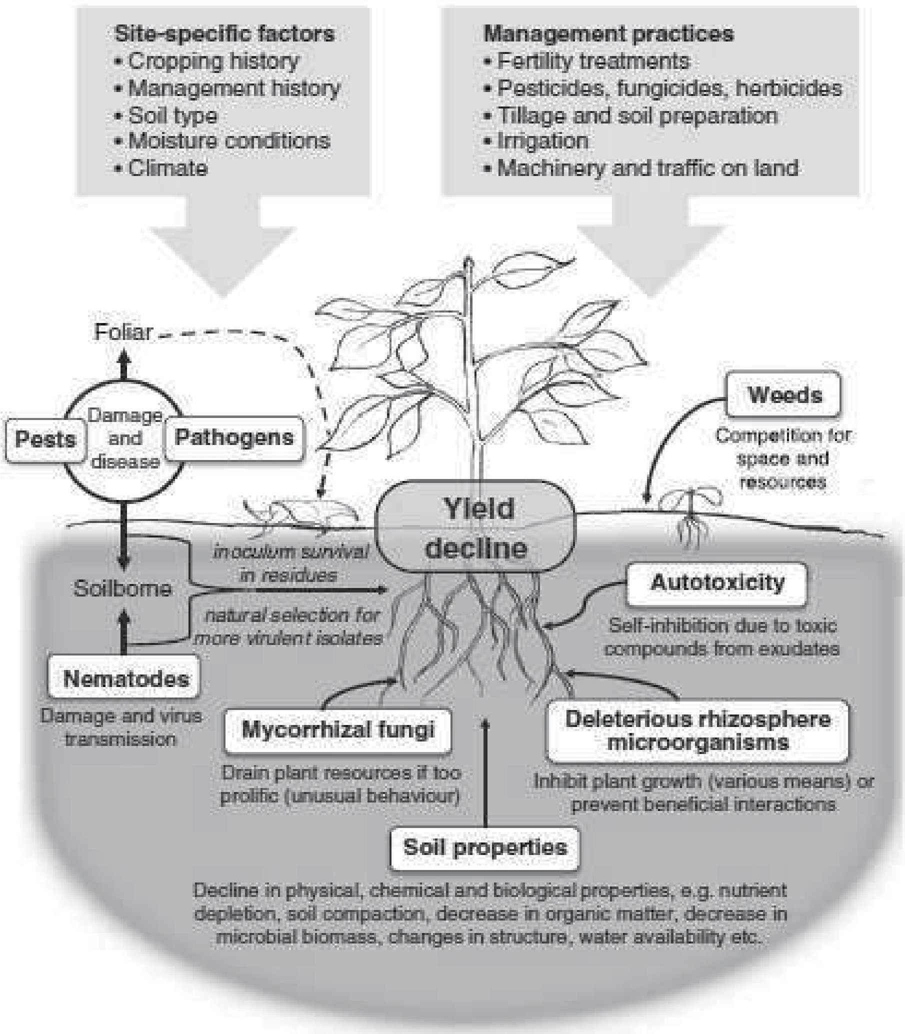

Figure 3. Representation of biotic and abiotic factors implicated in yield decline of crops (Bennett *et al.*,2012).

V – Key actions (Pre/Post-harvest)

1. Innovative Integrated Crop Management (ICM) including Integrated Pest Management (IPM) and organic practices to increase quantity and quality of production

To date, the main approaches for the control of disease are: chemical and biological control, host-plant resistance and cultural practices. Each of them has its own strengths and weaknesses. Chemical control has been practiced for many decades, using non- systemic fungicides and pesticides based on copper and sulphur compounds. These have been replaced since the early 1960s with systemic pesticides which are more specific and effective, although the older generation of pesticides is still used in developing countries because of their lower cost.

However, the risk of selection of resistant pathogens together with the growing concern about the toxicity of these products and their impact on the environment have led to the development of international standards that require the use of products with low toxicity and low environmental impact. Biological control has been extensively studied for more than 25 years and can be used successfully in certain situations. However, several limitations have become apparent when used exclusively on a commercial scale such as lack of reliability of disease control and the need for optimum environmental conditions for a satisfactory outcome. Plant breeding for disease resistance is a very important tool in disease management programs, and some plant varieties resistant to particular diseases have proved to be very effective. In some cases the resistance has proved to be remarkably durable but more often it is overcome by variants of the pathogen. Marker assisted selection (MAS) can aid the process of breeding effective genes into crops and, of course, the GM approach has high potential for maintaining the resistance of our crops to disease. Cultural practices such as crop rotation, pruning and the planting of barrier crops are probably the oldest instruments of control and have significant effects in reducing inoculums and encouraging antagonists in the soil. However, crop loss often remains too high despite the application of these methods, which therefore need to be complemented by other strategies.

2. Resource use efficiency

Organic farming practices should be oriented towards the efficient use of water, nutrient and energy use by the following strategies: preservation of soil fertility by recycling on- farm residues through composting, planning long rotations cycles among different plant species, introducing cover crop mixes with specific functions (green manure, bio- fumigation, soil structure enhancement), improving crop diversification. Biofumigation is based on the incorporation of fresh plant mass into the soil, which will release several substances able to suppress soil-borne pests. It reduces weed competition and soil-borne pathogens and is a suitable tool for soil disinfection. So far, Integrated Pest Management practices have increased ecosystem efficiency by reducing the overuse of insecticides and encouraging natural predation. Protecting the environment of production by the use of glasshouses or unheated plastic tunnels and using recycled rainwater could improve yield per unit area of land and per unit of water. However, such techniques require practitioners to be versed in them and their appropriate use to suit specific environments, which implies knowledge transfer.

3. Early diagnosis of the causal agents of the main diseases through innovative techniques

The early and rapid monitoring of disease in the field is essential in order to be able to take action to limit losses and to maintain the high quality of the harvested product. Until now this was achieved by frequent sampling, but this practice is not always possible as it is time consuming and requires well trained staff. Remote sensing systems use fewer personnel, facilitate the monitoring of large areas and can give more reliable results. However, laboratory tests would usually be required to identify the causal organisms of the diseases.

Recent developments in molecular, serological and electronic sensor technologies have led to a broadening of the capacity to detect pests and diseases and could improve application of crop protection practices. These alerts or sensors can be space-borne (satellite), air-borne (airplane, unmanned aerial vehicle) or ground-based (handheld, vehicle-mounted). Since 2001, research on these systems has been ongoing in order to create efficient intervention tools for the identification of pests and pathogens which are highly variable in space and time (Nutter, 2001; Nutter, 2004; Nutter *et al.*, 2006). As a result, crop protection activities may be tailored to achieve effective control when and where needed. Such innovative technologies should be established in the Mediterranean region. The data generated may then be used by scientists to monitor and analyze online the spread of pests and diseases in order to take steps to prevent them. For example, in combination with application of an agricultural decision support systems (DSS: see below), a decision may be reached as to whether pesticide use is necessary or not.

4. The application of agricultural Decision Support Systems (DSS).

The early diagnosis of the main pests and pathogens through innovative techniques on a small or large scale is fundamental to the application of (DSS). Identification is mainly based on biological, serological and molecular techniques which are constantly evolving to reach a larger-scale and higher sensitivity. Among these, molecular diagnosis by different methods such as biosensors and LAMP PCR are the most efficient owing to their high specificity and sensitivity. DSS is a computer-based information system that supports economic decision-making activities consisting of three basic components: i). DATABASE, containing large amounts of organized and retrievable data. ii). MODEL, a representation of an object, a concept or a system. iii). USER, a system that allows interaction between machine and user. Current techniques are not sufficiently advanced to manage large numbers of samples and to detect all relevant pests and pathogens but recent developments in molecular, serological and electronic technologies as well as in proximal and remote methods have led to improvements. The integration of DSS and IPM is the rational way to reduce pesticide use and consequently significantly reduce pesticide residues. Together they should allow the early detection of pests and pathogens in the Mediterranean region while numbers are still low and allow speedy and cost effective intervention. This platform of information should create a high level of collaboration among governmental agencies, farmers, growers and agribusiness societies.

5. Accurate and rapid monitoring of food contaminants and pesticide residues

The analysis of the presence of microorganisms has been performed for a long time using serological and microbiological methods. However, these are time consuming and are not compatible with current trade requirements or with the need to take action for control promptly. For these reasons, molecular techniques of detection and quantification have been developed in recent years. These enable accurate diagnosis of infection or infestation at early stages, giving control measures greater chances of success. On the other hand, as these methods require the use of specific expertise and are rather expensive, they must be used in a targeted and informed way. Furthermore, technical problems inherent in the complexity of the food matrices to be tested are still unsolved. In order to tackle this problem, the scientific community is making great efforts to decrease time and cost of analyses and to develop easy-to-use protocols with the aim of applying them.

6. The use of innovative technology and eco-compatible methods to reduce post-harvest losses and to control crop contaminants

During post-harvest, the development of ‘storage fungi’ represents a real threat as they are able to grow and synthesize mycotoxins when moisture content is relatively low (between 0.71 and 0.90 aw). Species of Aspergillus and Penicillium, producing aflatoxins and ochratoxins, respectively, belong to this group. In the Mediterranean basin, aflatoxins contaminate dried fruits and nuts, while ochratoxin A is often present in grapes and raisins. The severity of contamination is worst during drought years when plants are stressed and their resistance consequently low. Moreover, insect attack opens the way to infection even by fungi that are weak pathogens. Physical, chemical and biological control methods have all been used with varying degrees of success.

Physical control: Reducing the water content of the material to be stored, where appropriate e.g. grain, is an effective means of preservation and can be applied also to some non-grain crops e.g. tomatoes (Nonclerq *et al.*, 2009). Refrigeration is effective but expensive as is maintenance of low humidity. Recently, the use of modified atmospheres has given good results, in particular ozone treatment, which requires little investment, is easy to manage, sustainable and eco-friendly. Chemical control: Although control of food contaminants with compounds such as sodium nitrite and benzoic acid has a long history, concerns about the safety of their use has prompted the development of Biological control. Here the use of various peptides and chitosan, among other natural products, has shown promising results.

VI – Suggested research needs

Food security for the world's increasing population demands attention to the quality and quantity of crop production.

Food security, sustainability and ecosystem services at regional and global scale should be achieved in a cost-effective way. However, the nutritional value of food should be assessed because it varies according to the crop's genotype, to the environmental conditions and to the methods of production. The qualitative level achieved at harvesting time should be maintained from the field to the table during post harvest. There is a lack of research in determining production systems able to yield nutritious food with long storage potential. The identification of innovative best practices for an integrated and sustainable management and control of biotic and abiotic factors (both during pre-harvest and post-harvest stages) is fundamental to enhancing quantity and quality of the products. To this aim, research should focus on the efficiency of IPM and organic production systems under an eco-functional intensification approach, which can be pursued through the following 10 point plan, involving all actors in the food chain from farmers through researchers to retailers. This requires political will, scientific expertiseand financial support. Providing these are forthcoming, the security of access to nutritious and safe food for all should be attainable.

1. Development of early pest and pathogen detection;
2. Development of early pest/pathogen alert systems on a large scale through innovative agricultural decision support systems (DSS);
3. Adaptation of cropping systems to climate change and to biotic and abiotic stresses by genetic improvement of crops and increasing agro-diversity;
4. Improvement of water and nutrient efficiency of agriculture without reducing food production by targeting particular 'hotspots' of low efficiency;
5. Development of the quality of nursery production by innovative eco-compatible methods;
6. Enhancement of protected cropping system for meeting local fresh food needs;
7. Setting up of innovative rapid and accurate tools for detection of toxins, pesticide residues and other food contaminants on large and small scales;
8. Application of post-harvest innovative practices using environmental friendly technologies such as Ozone and Electrolyzed water;
9. Increasing the natural resources use efficiency for food production and improving the widespread availability of food in the poorest areas;
10. Integration of traditional knowledge and innovative agronomic practices;
11. Harmonization of innovative technical protocols in the production systems.

References

Bennett A. J., Bending G. D., Chandler D., Hilton S. and Mills P., 2012. Meeting the demand for crop production: the challenge of yield decline in crops grown in short rotations. *Biol Rev Camb Philos Soc*, 87(1): 52-71.

De Schutter, 2011. Agroecology and the Right to Food, Report presented at the 16th Session of the United Nations Human Rights Council [A/HRC/16/49]

FAO 2010. Sustainable crop production intensification through an ecosystem approach and an enabling environment: capturing efficiency through ecosystem services and management Rome, FAO. COAG/2010/3.

Foley A. J., Ramankutty N., Brauman A. K., Cassidy S. E., Gerber J. S., Johnston M., Mueller D. N., O'Connell C., Ray K. D., West P. C., Balzer C., Bennett E. M., Carpenter S. R., Hill J., Monfreda C., Polasky S., Rockström J., Sheehan J., Siebert S., Tilman D., Zaks D. P. M. 2011. Solutions for a cultivated planet. Nature, 478: 337-342.

Giovannucci D., Scherr S., Nierenberg D., Hebebrand C., Shapiro J., Milder J. and Wheeler K., 2012. Food and Agriculture: the future of sustainability. A strategic input to the Sustainable Development in the 21st Century (SD21) project. New York, United Nations. Department of Economic and Social Affairs.

Godfray H. C. J., Beddington J. R., Crute I. R., Haddad L., Lawrence D., Muir J. F., Pretty J., Robinson S., Thomas S. M., Toulmin C., 2010. Food Security: The Challenge of Feeding 9 Billion People. Science, 327(5967): 812-818.

IAASTD, 2009. Agriculture at a crossroad: synthesis report.

ICROFS, 2009. Results from research in organic food systems. fact sheet International Centre for Research in Organic Food systems. No. 2.

Nutter F., 2001. Disease assessment. In: Malloy O. and Murray T. (ed). Encyclopedia of plant pathology. John Wiley and Sons, Inc, New York.

Nutter F. W., 2004. Developing forensic protocols for the post-introduction attribution of threatening plant pathogens. Phytopathology, 94(6): S77-S77.

Nutter F. W., Esker P. D., Netto R. A. C., 2006. Disease assessment concepts and the advancements made in improving the accuracy and precision of plant disease data. European Journal of Plant Pathology, 115(1): 95-103.

Powlson D. S., Gregory P. J., Whalley W. R., Quinton J. N., Hopkins D. W., Whitmore A. P., Hirsch P. R., Goulding K. W. T., 2011. Soil management in relation to sustainable agriculture and ecosystem services. Food Policy, 36: S72-S87.

Prusky D., 2011. Reduction of the incidence of postharvest quality losses, and future prospects. Food Security, 3(4): 463-474.

SCAR, 2011. Sustainable food consumption and production in a resource-constrained world

Scialabba N., 2007. International conference on Organic agriculture and food security. Rome, Food and Agriculture Organization of the United Nations.

Spiertz H., 2012. Avenues to meet food security. The role of agronomy on solving complexity in food production and resource use. European Journal of Agronomy, 43: 1-8.

Thomas M. B., 1999. Ecological approaches and the development of "truly integrated" pest management. In: (eds). Proc. Natl. Acad. Sci., USA 96, 5944-5951

Tscharntke T., Clough Y., Wanger T. C., Jackson L., Motzke I., Perfecto I., Vandermeer J., Whitbread A., 2012. Global food security, biodiversity conservation and the future of agricultural intensification. Biological Conservation, 151(1): 53-59.