Focus Group *Organic Farming*

Mini Papers

Papers written by the experts

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1.1 Inadequate nutrients supply: innovation and key elements for success

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Introduction

Organic agriculture relies on crop rotations to manage nutrient cycling and to break the reproductive cycles of pests, weeds and diseases. Crop rotation does not necessarily mean that organic fields will be empty or cropped to non-food species when the main crop is not there (Tittonell, 2013).

Organic farming as a means for ecological intensification of agriculture in Europe requires a systems approach to farming that considers processes at the field, farm, landscape an regional scales. It is much more than conventional agriculture without inputs. Implementation at larger scale will require integration of activities within individual farms and also between different farms. It will require a more collective design (Titonell, 2013).

Through increased eco-efficiency, ecological intensification can contribute to higher productivity and yield stability. This means making more efficient use of natural resources and processes, improved nutrient recycling, innovative agro-ecological methods for making optimal use of nutrients in the soil. It is builds on knowledge of all stakeholders involved and relies on powerful information and decision making tools in combination with new research knowledge and tools in ecological sciences (Schmid et al., 2009). Concerning nutrient recycling of waste products from the food chain beyond the farm gate, stakeholders from many parts of the society, e.g. municipalities, biowaste plants and pulp industry need to be involved, not only from the agricultural and food sector.

Organic cropping systems need to be productive, stable (yield and quality) while at the same time robust, resilient and environmentally friendly. Adequate nutrient supply is crucial in such systems. Research is needed to contribute to improved nutrient availability, recycling, self-reliance in supply through innovative systems and new crop combinations. This means recycling of quality nutrient sources from agriculture, industry and also society. Improved techniques and information systems are crucial to have the right knowledge available for stakeholders involved. Also a combination of applied research, experimental and on farm knowledge development is necessary in combination with innovative designs, new technologies and integrative theoretical studies.

Areas of study have to include (1) Design of farming systems at all levels from the field to regional adapted systems, (2) Improved nutrient support through new crop combinations (intercropping, mixtures, different rooting depths etc.), (3) Improved fertiliser recommendations (4) Improving productivity at low nutrient levels, (5) Improved nutrient design by closing cycles at the farm, with industry and society (6) Innovative support tools and (6) Nutrients and adaptation to climate change and environmental conditions.

Key challenges and elements for future research

1. Design of farming systems at all levels from the field to regional adapted systems.

Sustainable production of organic plant and animal products requires balancing nutrient supply and demand throughout soil – crop – animal – manure cycles. Such cycles may be distinguished at field, farm and regional levels. At each of these levels, specific knowledge gaps exist related to both bio-physical processes as well as economic and regulatory context that support or inhibit innovation.

Analysis aimed at understanding causes should be combined with design-oriented research to explore how changes in nutrient provisioning affect economic, environmental and social objectives of agricultural production across the diversity of European production systems.

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To improve nutrient use efficiencies along with other indicators of sustainable development, the design-oriented research approaches should be embedded in co-innovation processes and a participatory approach (Koopmans et al., 2014) in which locally relevant solutions are developed by stakeholders who use research results for action.

2. Improved nutrient support through new crop combinations (intercropping, mixtures, different rooting depths in rotation etc.).

Intercropping, crop and variety mixtures and agroforestry systems can support an adequate nutrient supply on farms. Careful matching of secondary crops with the primary crop and growing conditions (e.g. root systems not competing but supplemental, combinations of nitrogen fixing with non-fining crops) is needed based on plant appearance, timing of growth phases and complementarity of resource and nutrient use. Especially in high yielding areas, combinations with new techniques like innovative harvesting techniques, direct sowing in a standing crop and GPS techniques is promising to increase the overall output of organic systems.

Perennial farming systems with tree, bush or vine crops also provide opportunities to combine an efficient use of nutrients with a more multifunctional use including annual crops. Also free range animal systems offer a high potential for increasing yields (multifunctional use of crop yields, fuel and feed production in the same area). The impact of these 'improved nutrient support system' is an increased yield and overall biomass production.

3. Improved fertilisation recommendations.

Research focusing on soil N availability including N release from soil incorporated plant residues and green manures to match crop demand is most crucial. Improved fertiliser recommendations based on experimental data are required to increase organic crop yields, taking into account both short-term and long-term effects. Research on different kinds of manure and other organic inputs which may act as short-term releasers of N may be required for fast growing crops. One example is digestate from biogas plants, which contain a large proportion of plant available nitrogen of total contents of nitrogen, and may be one new nutrient source of importance to European organic producers, if appropriate quality schemes are set up. Especially autumn sown crops which need available nutrients very early in the growing season would benefit from short-term releasing fertilisers. Composts and other organic products with high dry wait may not be decomposed and nutrients not released if supplied in spring in a growing autumn-sown crop. More knowledge on the quality and nutrient release pattern from actual and potential organic fertilizer sources are needed to improve fertilisation recommendations. Research to keep nutrient losses (particularly labile N) to a minimum is needed, both during the composting process but also during field application and during the cropping season.

Also in animal husbandry systems, grasslands, nutrient availability to crops is often insufficient due to lack of knowledge but also problems with maintaining clover content and N-fixations. Clover "fatigue" is more and more a problem in organic dairy production systems but the exact rational behind it is not yet known. Recommendations should be developed for organic condition, based on regional soils characteristics and condition and inputs available to organic farmers.

4. Improving productivity at low nutrient levels.

Worldwide the commercially available phosphate resources, used to produce phosphorus fertiliser, are decreasing and phosphorus efficiency of agricultural systems becomes an item of uppermost importance to farming.

Some organic farms and certain areas have a long history of low phosphorus inputs, very low soil phosphorus levels according to existing analyses but apparently perceive no real phosphorus limitations on yields. Potential explanations can be found in the contribution of organic soil phosphorus to plant nutrition, the typical organic rotations including 6 to 7 different crops with a high percentage of legumes (some of which are known to mobilize phosphorus from pools in the soil for crops), and the soil structure and quality opening up to soil to plant nutrient uptake. Also 'natural' rock phosphate and ground limestones can be used to increase soil pH and phosphorus availability. But the combined effects of lime, rock phosphate, composts or other organic amendments on organic crop production are unknown.

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Research should focus on these organic low phosphorus (and potassium) input systems to learn about the dynamics of soil phosphorus (and other nutrients) and soil factors influencing mineralisation and availability in the cropping system.

5. Improved nutrient design by closing cycles at the farm, with industry and society.

Closing nutrient cycles at the appropriate level is a challenge increasingly important. Especially phosphorus and potassium sources will diminish and are hard to replace without mineral sources. Research should focus on quality and available of the nutrients from recycled waste, of various origins and evaluated in terms of its sustainable use *on*-farm and within the organic requirements of today and beyond, as organic regulations are continuously developing. The quality and sustainability of different inputs into organic farming should be carefully evaluated and sustainable alternatives developed. Combination with waste from organic sources, recycling for instance from retail and supermarkets is an area becoming more and more important as the amount of products sold and the amount of waste produced in these channels, increase. The largest quantities of nutrients in the food waste system are found in human excreta. There is now not an option to recycle these sources in organic production. In a more long-term perspective, however, if new solutions and possibilities are being developed, e.g. source separating systems, this nutrient source could make a large contribution to sustain nutrient needs in organic production. Research on sustainable and resource efficient solutions for recycling systems of these products are consequently important.

Taking into account the degradation of soils and low levels of organic matter in most Mediterranean countries there is a need to research the feasibility of short and long term use in agriculture of a wide variety of industrial and societal waste products. Quantifying nutrient becoming available from organic amendments during the first growing season must be investigated but also the residual nutrient (particularly nitrogen) effects after the year of their application, to develop nutrient recommendations for organic farming.

Farm specialisation requires appropriate options of closing nutrient cycles at local or regional scales between organic enterprises. As the number of mixed farms tends to decrease, regional options should be clearly defined. Also socio- economic obstacles for recycling nutrients should be identified and taken away. The same is true for feed production tending to move to areas far from consumer sales. Viable options to close nutrient cycles with these areas should be developed.

Organic farming can play a leading role in developing a circular economy within the food and agri business. The short chains, the certification schemes and transparent approach makes it an ideal pilot area to develop these innovations.

6. Making use of innovative support tools (models, techniques and production support tools).

Support tools like support models, soil and plant analysis, GPS, but also mobile phone applications are largely developed based on systems with high artificial inputs and conventional soil conditions. Also soil analysis recommendations adapted to organic and low input systems are hardly developed. This is becoming an increasing problem as more farms turn into organic conditions European wide. Managing biological processes in soils and farming systems is seen as a key for a more sustainable farming option and innovative tools should be developed to support it. For instance: nutrient availability in the soil is based on water-soluble nutrient levels not taking into account mineralisation or availability from organic matter sources. Standard simulation models take into account 1 year of crop production not accounting for a system or even crop rotation necessary or common within organic practices. Standards for "good" biological soil fertility do not exist. Organic farming considers biological activity in the soil, rotation, interaction and prevention of uppermost importance. Tools to support decision making, and to support what is going on at more complex and low input systems should be developed to increase understanding and improve production for these new systems.

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7. Nutrients and adaptation to climate change and environmental conditions (climate change, water surpluses and shortages).

Organic production systems rely on maintaining or increasing soil organic matter to improve the physical, chemical and biological soil fertility, in order to sustain crop production. Soil fertility is maintained primarily through the use of leguminous fertility building crops, nutrient cycling on the farm and the regular application of green manures, farmyard manure and compost.

Soil organic matter, macronutrient, and micronutrient levels go up by organic inputs but its final level also depends on the rate of decomposition, soil properties, and climatic conditions. The net effect of this management is an increased soil carbon sequestration in several organic farming systems (Drinkwater et al., 1998; Mäder et al., 2002). In addition, soil structure and water holding capacities are increased, soil erosion reduced and an overall improved adaptation to environmental and climatic changes achieved.

When applying compost and other inputs, the challenge is to know the composition and to understand and use it most efficiently. Research should therefore focus on the contribution of these organic management practices on nutrient supply versus carbon sequestration, water holding capacity, potential to reduce erosion and its impact on soil fertility.

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2.1 Poor soil fertility: Farming systems

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Introduction

Productivity in organic farming systems is mainly based on enhancing soil functioning by maximising internal nutrient cycles. Thus, these systems aim to build up soil nutrient reserves, mainly in soil organic matter. To do so they recycle all resources available on farm while enhancing the use of biological processes such as N fixation, rotations, cover crops and/or multiple crops. Furthermore, in organic farming systems the size and diversity of the arable fields has great importance as it implies the ecological functionality of the landscape.

As mixed farming systems have organic resources on farm they are well set to optimise the use of animal manure. These systems greatly contribute to the environmental services such as enhancing C sequestration, soil and water quality and biodiversity of the agricultural landscapes. However, nowadays these systems are only a small part of the organic farms in Europe and they will not necessarily adapt to all possible organic scenarios.

On the other hand, organic stockless arable systems are highly abundant throughout Europe. These systems have to enhance N fixation in crop rotation and minimise nutrient losses with an improved use of catch crops to sustain their yields. In the event these cropping systems are well managed, they can balance for N and even increase soil C content. However, these systems cannot balance for nutrients such as P or K without the use of off-farm organic sources such as animal manures coming from other non-intensive farms, compost or non-industrial mineral inputs such as rock phosphate.

Organic farming systems are intricately linked to their environment and to their socio economic context, so their performance is highly site dependant. This makes it difficult to directly spread the knowledge gained in one farm to another and makes difficult to elaborate general guidelines for broad areas such as Europe. However, the main headings for a sustainable and innovative organic farming in Mediterranean and temperate European agricultural areas should be defined to provide common guidelines on organic farming to be followed when improving cropping practices at national and regional scale.

Organic farming in temperate and continental areas has variable constraints according to different agro-environments; however, abiotic stress conditions due to flooding and other extreme events which are increasing with changing climatic conditions, should be taken in consideration when improving cropping practices and rotation cycles of arable crops (ICPP, 2007). Another important item is improvement of soil functioning to increase yield stability of organic productions. This could be reached by introducing new varieties with increased resistance to biotic stress or by increasing soil microbial diversity able to induce plant stress resistance and reduce the impact of their secondary effects such as the increase of secondary pathogens agents of root rot and dumping off and many other plant diseases which are stress-mediated. The cropping systems of temperate areas are generally characterised by a sufficient content of organic matter, therefore cropping practices should lead to an increase of soil biological fertility by introducing new agro-techniques suitable to maximise natural available resources by minimising the recurrent problems of organic management such as Nitrogen losses in autumn, temporary N immobilisation in the short – medium period after green manure**,** peak of mineral nutrient availability for crops during growing season, etc. Other aspects of the biological fertility that should be considered and optimised in organic farming systems are: (1) Symbiotic Nitrogen fixation that should always aim at positive N balances in the cropping system. This includes below-ground crop N dynamics. (2) Non legume rhizospheric Nitrogen fixation such as that of C4 plants. (3) Field scale knowledge on the processes of biological mobilisation of other nutrients such as phosphorus and potassium.

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The incorporation of conservation agriculture techniques (e.g. no tillage and reduced tillage and green manures) in organic farming systems brings many benefits to the environment and reduces energy use. For this reason, it is a challenge integrating conservation agriculture techniques into organic farming systems to improve soil fertility, nutrient use efficiency, yields and sustainability. However, nitrogen management techniques may need to be adapted when reduced tillage systems are introduced, taking into account impacts of changes in soil conditions (e.g. soil water, organic matter and temperature) and weed competition on the availability patterns of N. More research is needed because of limited information on how to manage N fluxes following the introduction of conservation agriculture innovations.

Organic farming in dry areas has some specific constraints relative to the low or very low stock density and subsequent manure availability and to the difficulty of designing complex crop rotations because of the extended length of drought periods. Under these conditions the number of crops, including legumes, that can be included in crop rotations is reduced; therefore, appropriate actions aiming at recuperating robust legumes adapted to local conditions are a key point to ensure sufficient N availability to those cropping systems. This need raises the problem of commercialising new products that often have no room in the conventional commercial cycles. The other main problem of those cropping systems is the intrinsic organic matter depletion of Mediterranean agricultural soils, which imposes to organic farmers to adopt strategies aiming at increasing soil fertility to obtain sufficient yields not only for their profit but also for maintaining the soil function. Thus, there is a need to define minimum yields for soil protection. Under these conditions organic farming systems assume the additional role of environmental service. In the frame of organic farming the agronomic techniques to raise the levels of soil organic matter have a major importance. This includes the use of reduced tillage or no tillage and the use of stabilised sources of organic matter. However, weed control is a major problem in no tillage or reduced tillage systems under organic farming, especially for perennial weed species. The agronomic techniques related to the use of stabilised manures such as compost of different origins and qualities deserve a special attention. Indeed, the application of these products is needed both for increasing SOM level in conversion and in maintenance of fertility of organic cropping systems. In this frame, agronomic and composting technologies need to be merged and optimised with specific policies to support it. Soil biological fertility is also to be considered in the dry areas.

Urban and peri-urban organic farming is a rising reality of organic agriculture. In contrast with traditional organic farm of rural areas, urban and peri-urban organic farms cannot increase and maintain their soil fertility by simply using in-farm resources. Although this fact raises a difficulty for organic farming in urban and in industrial areas, urban organic farming might contribute to build up the sustainable cities of tomorrow. For that purpose, urban and peri-urban organic farms should be able to include in their cropping cycle the organic resources generated in cities, after suitable separate collection of the domestic organic waste and that deriving from food processing industries. This is already being implemented with success in many cities and regions scattered in several European countries. The implementation of these systems goes beyond the farmer capabilities as it needs the contribution of the local authorities, the stakeholders and even that of the inhabitants of the cities.

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2.2. Poor soil fertility: Crop rotation (including pests and diseases management – compost, system, ICT)

JOHANN BACHINGER, STÉPHANE BELLON

ROLES OF ROTATIONS TO IMPROVE PERFORMANCES IN ORGANIC CROPPING AND AGRICULTURAL SYSTEMS

Introduction

An expansion of European organic farming requires increased crop production performances, which entails higher and stable crop yields to bridge the yield gap on the one hand between conventional and organic farming and on the other hand between different farms and the yield potential found in some areas or under optimal management practices conditions (e.g. in some field experiments) (Guyomard, 2013). This must be achieved while ensuring integrity of the organic production, placing less reliance on external nutrient supply like conventional manure (Oelofse *et al.,* 2013), reducing environmental impacts from organic crop production and shifting from the specialisation trend in organic cropping systems which took place in the 90s (David, 2000). Subsequently, diversification at cropping and farming systems levels is still at stake. Such a diversification is also widely constrained by existing CAP regulations and lock-in effects in commodity chains. EIP-AGRI could provide an adapted framework to design and sustain new value chains likely to support the implementation of agronomical, technological and organisational innovations through "local groups of innovation" and valuation of knowledge and experiences (Meynard *et al*., 2013).

Studies undertaken in many European countries have identified limited nutrient (in particular nitrogen (N)) availability and weed pressure (in particular from perennial weeds) as being the primary reasons for low yields in cereal and vegetable crop production (Peters, 1991; Berry et al., 2002).

Organic farms are essentially run without the application of mineral N fertilisers and synthetic pesticides and with limited external inputs of organic fertilisers and forage. Due to these restrictions, crop rotation design is one of the major instruments applied (i) to manage the nitrogen supply of crops (e.g., Olesen, 1996; Vereijken, 1997; Watson et al., 2002), (ii) to control weeds (e.g., Barberi, 2002; Melander et al., 2005), (iii) to control soil-borne pests and diseases (e.g., Vereijken, 1997, Valantin-Morison & Meynard, 2009), and (iv) to ensure sufficient forage production and the optimal use of manures (in organic mixed farms).

In particular, stockless organic farms require the development of suitable soil fertility building strategies due to the limited availability of organic nitrogen sources (David, 2005). Colomb *et al.* (2013) stated a high potential for the development of more sustainable cropping systems of stockless organic farms. Nutrient budgets are useful evaluation tools at farm and field level for managing long-term soil fertility in organic farming systems (Watson et al. 2002).

As chemical control is not an option for weed management in organic farming, a combination of methods is required, integrating diverse rotations, including diverse leguminous and non-leguminous crops, break crops and cover crops and highly competitive crops (e.g. bioenergy crops), cultural methods to increase the competitiveness of crops and physical control methods (Barberi, 2002). Improved crop rotation planning has to take into account regionally different problematic winter and spring annuals and perennial weeds at the same time (Bachinger, 2007). Especially perennial weeds like *Elymus repen* and *Cirsium arvense* can become a serious problem in organic agriculture (Salonen, 2008; Lundkvist, 2008).

Beyond this East (2013) stated the huge positive effects of cover crops and crop rotations on soil microbial populations improving plant growth and drought resistance.

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Many questions on nutrient cycling weed dynamics and phytosanitary issues, in particular soil-borne diseases of legumes require long term observations (field experiments and on-farm research) as management measures may have mainly a long term effect and changes be slow. Along with the annual variations it is difficult for organic farmers and advisors to assess the sustainability of present cropping systems implying crop rotations and tillage systems respectively. To correct occurring damages related to N supply, weed control and phytosanitary issues in organic farming only very few agronomically and economically feasible measures are available. Therefore nutrient and weed management and phytosanitary issues need to be addressed jointly at the long-term cropping system level and a site- and farm specific crop rotation design is crucial.

However, careful planning of crop rotations to ensure agronomic sustainability is highly complex, because N fluxes, weed management, and phytosanitary issues have to be considered throughout a complete rotation period and be consistent with organic principles. Regional, site and farm specific crop rotation planning and/or evaluating tools can help farmers and advisors to cope with this task.

Solutions/possibilities

Several crop rotation/cropping system planning and evaluating tools has been developed and briefly listed below. Most of the tools have been only regionally developed, adapted and tested. Models adapted to organic situations often focus on single performances (e.g. Casagrande *et al.*, 2009) or management techniques (e. g. Guichard *et al.*, 2013), with rotation as a context. Their relevance to study or improve farmers practices can thus be questioned (e.g. Nesme *et al.*, 2005).

It could be stated that the user-friendliness and usability of most the tools has to be improved, but bridging the gap between scientific tools and tools usable for advisors and farmers is hampered by two obstacles (i) funding difficulties, (ii) limited knowledge about crop sequences actually implemented by organic farmers (Bellon & Doré, 2004; Le Ber et al., 2006), especially during transition periods, and (iii) limited scientific output of needed transfer projects.

There is still a gap of regionally applicable knowledge concerning weed control and phytosanitary issues of actual crop sequences and rotations under organic farming conditions. An extraction of the knowledge from crop rotation experiments and on-farm research can give valuable new insights of organic crop rotations to improve crop rotation planning. Interactions with stakeholders (farmers, advisors, processors etc.) have to be used for regional adapting and testing of the different models/tools.

In addition to software tools, guidelines- some are listed below- can provide practical support for farmers and advisors with limited IT experiences for crop rotation planning.

Crop rotation/cropping system planning tools

- Vereijken (1997) developed a manual system for designing and evaluating multifunctional crop rotations as a major method of ecological farm prototyping. This includes crop specific semi-quantitative parameters and rules concerning biological soil fertility (maximum shares of crops and crop types), soil structure, chemical soil fertility (nutrient balances for N, P and K) and agronomically feasible crop successions.
- The crop rotation planning tool ROTAT, (Dogliotti et al., 2003) is based on a static approach developed by Vereijken (1997). ROTAT has been applied for crop rotation planning in two different case studies in the Netherlands in South Uruguay with small conventional vegetable farms. ROTAT combined evaluation tools focus on phytosanitary issues, soil erosion and the use of pesticides and the long term dynamics of soil organic matter (Dogliotti et al., 2004).
- ROTOR, a crop rotations planning tool for organic farming systems has been developed by Bachinger and Zander (2007) for organic farming systems in central Europe. Assessment modules for site and preceding crop specific crop yields, N-balance including N_2-fixation and nitrate leaching, weed infestation risks, phytosanitary and chronological restrictions and economic performance are included. Experiences are presently limited to East Germany. An

English version including a humus balance module will be available soon at: (**http://www.beras.se/implementation/index.php/en/2012-02-09-21-54-40/guidelines-for-ecological-recycling-agriculture/software-tool**)

- For low-input systems a specific model entitled MASC-OF was developed and applied to study stockless organic cropping systems. The MASC-OF model is original because it is based on agricultural advisers' needs and expertises. The methodology allowed advisers to design a model including their own views on what is a sustainable organic cropping system. Soil fertility and weed and pest control were integrated (Colomb, 2013).
- To address this general planning problem (Stone *et al.*, 1992; Dury *et al.*, 2010), several tools have been proposed as adapted to organic situations (Seppänen, 2000; Padel *et al.*, 2002; Mohler & Johnson, 2009), usually addressed at farm level or based on experimental stations (Fontaine et al., 2011). Conversely, planning beyond the farm or cropping system level is poorly documented. For instance to organise collective land use patterns, or to create more connections among organic farmers (e.g. to supply compost to stockless farmers).

Crop rotation evaluating tools

- The NDICEA model describes soil water dynamics, nitrogen mineralisation and inorganic nitrogen dynamics in relation to weather and crop demand (Van der Burgt et al. 2006). Crop yields are put in to the model, resulting in a target-oriented modelling approach which is distinctive from most other models. Parameter calibration is an inherent component of the modelling philosophy and is geared to establishing plot-specific factors. A user-friendly version can be downloaded: **http://www.ndicea.nl/indexen.php**
- The humus balance model (HU-MOD) is designed for application by farmers and extension workers in practice as *a tool for management support (Brock et al. 2012). To enable practice applicability, HU-MOD bypasses the need* for data on soil parameters and can be run with simple management data. HU-MOD is based on a simplified model on carbon and nitrogen pools and fluxes in the soil-plant system. The model proved to be an applicable simple tool for the comparison of management systems in arable farming with regard to the impact on SOM levels.

Guidelines concerning crop rotation planning

- Farming Guidelines provide practical recommendations for ERA. They present agronomic measures and optimisation strategies for effective nutrient recycling within and between farms during and after conversion within the Baltic Sea region. They also include crop rotation planning in organic farming (Stein-Bachinger et al., 2013).
- Legumes are the main N source of organic crop rotations, therefore the controlling of soil borne diseases of different legumes species including interactions within crop rotations has to be handled carefully. On-going projects as the German project Bofru (**www.bodenfruchtbarkeit.com**) has compiling crop frequency and sequence based crop rotation rules and examples concerning different legume species for farmers and advisors.

Perspectives

For developing new and improving existing modeling approaches there is still a significant knowledge gap concerning the dynamics and site specificity of multiple temporal and spatial interactions within organic cropping systems that has to be bridged through a synthesis of the outcomes (including failures) of existing and new designed long-term experiments and regional applicable expert knowledge.

Possible research avenues to fill such knowledge gaps could include:

- Including flexibility in the planning and implementation of crop sequences and related land use patterns, whereas rotations can be considered as a farmer model, usually differing from a crop sequence. Subsequently, identifying what is the range of possible rotations at regional level.

- Improved integrating of the role of preceding crops in securing higher performances in organic cropping systems, especially regarding so-called minor species who contribute to diversification in crop sequences.
- Connecting temporal and spatial dimensions (link between crop sequence and farm land use patterns), so that annual farmland use is also diversified.
- Developing or integrating tools to assess performances, their stability and robustness (inter-annual fluctuations) at cropping system level, including with more complex patterns (e.g. with agroforestry)
- Multi-performance and multi-criteria evaluation of rotations and their effects (e.g. considering consequences of bridging yield gap or other effects of crop rotations on product quality or environmental performances)
- Addressing long term dynamics (fertility and knowledge building) in transitions among rotations during and after the conversion period (long term planning) in an uncertain economic environment (opened to flexibility or adaptability issues)
- Scaling up niche innovations regarding crop diversification (how to integrate them in existing chains?) and combining various outputs (quantity and qualities). Among others, what are the threshold effects (such as minimum critical volume at regional level) enabling efficient marketing channels and multiple land uses.
- Strengthening a multi bio-aggressors approach through crop rotations (weeds, soil-borne and aerial pests and diseases)

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2.3 Poor soil fertility: Composting

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Introduction

The progressive decline of organic matter (OM) and organic carbon in cropland is a raising problem for soil fertility and productivity and its reintegration is critical. Soil degradation regards one fourth of arable cropland on a planetary scale[1]. On a European scale loss of soil is related to erosion, salinisation and acidification, desertification and soil organic matter reduction. This is particularly evident in the Mediterranean region based on pedology and climate (areas in Spain, Italy and Greece)[2].

In organic farming due to restrictions in off farm inputs, compost can be part of agronomic strategies to build and maintain soil fertility, particularly in organic stockless arable systems.[3]

Composting can be a specific topic:

- in areas where integration of SOM is necessary and/or where soil degradation is consistent;
- in areas with livestock slurry and high nitrate vulnerability, to improve the suitability of soil amendments and mitigate indirect effect of leaching on acquifers.

In organic farming (OF) management, special attention to preserve or possibly improve the content of SOM is not only aimed for plant nutrition but also to create the best conditions to improve soil quality, properties and functions, enhancing microbial activity, improving soil structure, water holding capacity, pH and other relevant soil parameters, increasing protection and resilience to climate change. The benefits of compost, besides delivering nutrients, are in the improvement of the soil's interaction with the plants which should tend, in the long term, to yield stability and higher crop health and quality. Enhancing the use of compost, best if produced on farm or within the farming system we are addressing, falls into a strategy that can contribute to reducing the yield gap and establishing satisfactory soil management systems for quality productions. Considering that compost has a significant carbon sink effect, increase in composting skills and practices on farm will allow to reduce other environment negative or forbidden practices such as burning organic by-products (leaves, branches, pruning residues etc.).

Types of compost – farm produced compost vs municipal and agro-industrial compost

Compost production on farm or in mixed farming systems does not appear to be widespread whereas research has been carried out to develop satisfactory technologies for composting municipal and agro-industrial organic waste and these technologies are widespread at present. Studies have been conducted, relating the impact of compost on soil and crops and comparing such results to the use of mature livestock manure, traditionally the main competitor of compost[4].

Research on vermicomposting, a decomposition process involving interaction between epigeic earthworms and microorganism, compared to composting without earthworms, demonstrated significant positive differences in product end quality. Main difference with the same input material

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[1] Lal R. "Challenges and opportunities in soil organic matter research" , *European Journal of Science , 2009*

[2] Ezio Rusco, Robert Jones &Giovanni Bidoglio "Organic Matter in the soils of Europe: Present status and future trends", European Soil Bureau, Joint Research Center , 2003

[3] CRA RPS – (Rome) is carrying on a project (COMPARABIMUS) on effects of compost in mediterranean organic stockless arable systems.

[4] Edited by C.R.P.A. – Atti del Convegno Bologna 15 aprile 2008, "Impiego in agricoltura di ammendanti compostati – Risultati di sei anni di sperimentazione"

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was higher reduction in organic carbon, increase in N instead of loss, increase in P and other nutrients.[5] Other research showed the ability of the microbial community of vermicompost to mobilise P and K into plant available forms through the use of compost extracts.[6]

In organic agriculture we would expect a higher use of compost, whereas it appears to be mainly related to higher value crops (as in conventional agriculture) and not as widespread as it could potentially be. This is due to a number of reasons such as longer term effectiveness, limited availability in nutrients, farmers' feeling of scarce convenience in terms of costs/benefits, insufficient equipment on farm, substitute products (livestock manure and digestate) and incomplete knowledge transfer.

The physicochemical properties of manures should be suitable for composting treatment (with or without the use of epigeic earthworms) directly without additional interventions, such as the use of bulking agents or frequent pile turning as aeration strategies that increase the cost and complexity, and reduce the practicability of on-farm composting.

The separation of liquid and solid fractions of livestock slurry can be advantageous to produce nutrient-rich organic solids and potentially reduce the nutrient and organic matter contents in the liquid phase[7]. The solids may be further processed by composting to improve the suitability and acceptability of the slurry solid fraction for use on agricultural land. This is particularly significant in Nitrate vulnerable zones.

Because composts can be exported to other farms with a high demand for organic amendments, well matured and stable compost presents advantages in respect to mature cattle slurry reducing the presence of undesired weeds and microorganisms. Furthermore, composts have the capacity to suppress soil borne pathogens.

Recent research examined the feasibility of a simple management approach to determine whether Acacia waste biomass, which is available in large quantities in countries like Portugal and Spain, was suitable as a feedstock for composting and for the production of valuable end-products such as soil improvers and substrate components[8]. The research demonstrated that waste Acacia biomass is indeed suitable as a single feedstock input for composting – it has sufficient biodegradability and structure for effective treatment in large scale composting piles, without additional materials and with minimal management interventions.

Release of nutrients (macro-meso-micro) with particular attention to N and effectiveness on production performance, and recommendations

On-farm composting of agricultural feedstock (crop residues, manures, green manures, etc.) should be the main source of compost for organic farms. However, other specific composts from outside the farm may be acceptable where integration of SOM is indispensable or for particular periods within crop rotation. For example, fast growing vegetables may require composts acting as short-term releasers of available N. Therefore, specific industrial food waste and domestic waste products, for example, may be feasible for composting and compost use for organic farming. However, compost

[5] Arvinder Kaur, Jaswinder Singh, Adarsh Pal Vig, S.S. Dhaliwal, Pushpinder J. Rup, Cocomposting with and without Eisenia fetida for conversion of toxic papermill sludge to a soil conditioner, 2010

[6] Walter Wenzel, Markus Puschenreiter , M. Wieshammer-Zivkovic , Auswirkungen der Applikation von Wurmkomposttee auf die Verfügbarkeit von P – Paradeiserversuch

[7] Brito, L. M., Mourão, I., Coutinho, J., Smith, S. R. 2012. Simple technologies for on-farm composting of cattle slurry solid fraction. Waste Management, 32: 1332-1340.

[8] Brito, L. M., Mourão, I., Coutinho, J., Smith, S. R. 2013. Composting for management and resource recovery of invasive *Acacia* species. Waste Management and Research, 31: 1125-1132.

quality and the agricultural use of composts from sources outside agriculture should be further investigated both for short and long term use.

Composts vary greatly in their composition, degree of stabilisation and ability to release nutrients for plants or protect them against diseases. Nevertheless, to successfully manage the cycle of nutrients in the soil it is necessary to estimate compost mineralisation rates and the influence that composts exert on soil processes and properties. A limiting factor in the use of excessive amounts of composts, particularly when they are not completely matured or not properly processed could result from toxicity caused by pathogens, high contents of salts, ammonia or other substances, or soil nitrogen immobilisation.

Although there is a need to increase soil organic matter content and soil carbon sequestration in the long-term to protect the agricultural soil and for environmental reasons, composts that may act as short-term releasers of nutrients for fast growing crops may also be required to improve crop yields, for economic reasons. However, the pattern of nutrient release from organic materials and composts is not fully understood and should be investigated to understand compost contribution to match nutrient availability for crops, for distinct composts and environmental conditions.

A deeper knowledge on the dynamics of nutrient release could also be a winning argument to convince organic farmers to use compost on a regular basis.

Soil N supply from composts depends on the initial availability of inorganic N in compost, the easily mineralised N from the labile pool of compost and the longer-term rate of organic N mineralisation of more recalcitrant compounds. The mature compost with high level of stabilisation may be a poor short-term source of N from mineralised organic N. However, mature composts where ammonia nitrification occurred may have nitrate-N that is immediately available for crop uptake. Especially in the vermicomposting process, loss of nitrogen is minimised compared to composting process without earthworms.[9] In contrast, immature compost may have high ammonia content but this is not beneficial for seed germination or root growth.

Concentrations of conservative nutrients usually increase proportionally to organic matter mineralisation, enriching the compost as an agricultural nutrient source. Nitrogen concentrations also increased to a degree, but are much more dynamic and losses are difficult to actively control, because nitrogen is a more labile nutrient. Therefore, the challenge is to keep nitrogen loss to a minimum throughout the composting process, for agronomic reasons and also to minimise environmental impacts and to minimise N loss during and after compost application. P fertility should be also taken into account considering the reduction of natural stocks, the complex nature of P reactions in soils and the frequently assessed long term negative balance in organic farming systems throughout Europe[10] .

Research, innovation and demonstration activities

Following a few research and innovation avenues:

- Development of efficient and simple techniques for compost and vermicompost production on farm, with minimum turning is needed to decrease composting cost (e.g. container composting: heat can be used, CO_2 can be used for fertilising greenhouse operation, no sealed composting areas necessary);
- Development of affordable compost quality tests, which measure more quality parameters (humic substances, plant growth regulators - PGR, microbial composition, nutrient availability) and risk parameters;

[9] Arvinder Kaur, Jaswinder Singh, Adarsh Pal Vig, S.S. Dhaliwal, Pushpinder J. Rup, Cocomposting with and without Eisenia fetida for conversion of toxic papermill sludge to a soil conditioner, 2010

[10] Aronsson H., Torstensson G. and Bergstrom L. Leaching and crop uptake of N, P and K from organic and conventional cropping systems on a clay soil, Soil use and management 23, 2007

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- Prevention of nutrient loss during composting (prevent loss and not pollute, also relevant for greenhouse gases);
- Further studies of long term effects of combinations of methods to implement SOM (crop rotation, green manuring, compost application);
- Further studies on compost nutrient content, dynamics, availability for plants, effects on microbial activity and on physicochemical parameters of soil and plant health;
- effects of small amounts of compost on crops (e.g. compost extracts, seed treatment, precise application during seeding) – research on processes, relationships and agents involved (i.e. PGR, humic substances, antagonistic effects, inoculation of microbes, which then can be multiplied by the plant itself);
- Long term research on the effect of risk parameters (heavy metals, pathogens, antibiotics, hormones, etc.);
- Development of amendment techniques for quality compost (rock dust, microbes);
- On field (near surface) composting with addition of microbes;
- Investigation of old recipes and procedures for compost production;
- Composting cooperations (reduction of costs, knowhow transfer in the group, demonstration activities, safety requirements)

Demonstration activities are vital for applied techniques, they should include "field days", videos and other visual support.

Recommendations for operational groups (OG)

EIP-AGRI represents a main opportunity to qualify organic farming over the 2014 – 2020 period and the good functioning of OGs, their capacity to interpret the needs of agricultural enterprises, bearing in mind a long term perspective and European vision on the future of agriculture, will be vital. Every effort should be done to make scientific information/innovation on the topic easily available.

As we argue, composting is particularly interesting/useful for Organic Farming but can be spread out also as best practices in conventional agriculture.

The projects should have concrete objectives to be tested and applied on farm and have a consistent dissemination plan from the start using also new information technologies. It is desirable to work on local systems involving farms with different extension/crops/land use to assess scale /land use synergies or constraints and scale adaptation of the project.

OGs should be in touch with existing networks and platforms and contribute to implement them (on a regional or better at a European scale) involving institutions interested in giving/receiving and disseminating information on the topic. OGs should involve groups of advisors, allowing participation of associations and stakeholders. For innovative projects on compost, OGs should include in the partnership institutions dealing with waste disposal, soil amendment and remediation, facilitating the introduction of successful innovation on a broader scale and verifying legal feasibility of results within EU legal framework and regional rules.

Moreover there should be some flexibility in the OG during the implementation phases of the project, so as to involve more participants if needed: OGs should be open and dialoguing.

For innovative composting techniques, demonstration activities should be the core of dissemination process including videos and webinar.

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2.4 Poor soil fertility: Tillage

WIJNAND SUKKEL

Tillage is a farming tool which influences many aspects of the farming system. It influences for example costs, nutrient availability, seed emergence, soil structure, weed pressure, disease pressure, water holding capacity, water infiltration and soil organic matter.

Tillage not only effects agronomic aspects but also different ecosystem services like biodiversity, water infiltration, erosion, carbon sequestration, greenhouse gas emissions and resilience to climate change.

Because organic agriculture does not use synthetic pesticides and synthetic fertilisers, shortcomings in soil quality cannot be counteracted with these tools. Therefore the importance of soil quality and with this the importance of tillage is in organic agriculture of increased relevance compared to conventional agriculture.

Compared to conventional agriculture, tillage in organic agriculture has a higher relevance in weed control, incorporation of organic matter, the availability of plant nutrients and sanitation of pests and diseases. For these reasons organic agriculture has a tendency to a rather intensive soil tillage management as (deep) ploughing and the frequency of tillage operations (mainly for weed control). Inversion tillage easily gets rid of weeds, (infected) crop residues and incorporates organic fertilisers and green manures.

Not only the type of tillage but also the timing of tillage in relation to the release of nutrients from organic matter is important. The timing of incorporation of crop residues, green manures and organic fertilisers influences the timing of the decomposition of the organic matter and as such the timing of the release of plant available nutrients. The pattern of the release of plant available nutrients is often not in line with the crop demand for nutrients.

As already substantiated in conventional agriculture, reduced tillage techniques, as a part of conservation agriculture strategies, have some clear advantages over strategies with intensive tillage. Some of these advantages are: lower costs, better water infiltration, less erosion, a higher soil biodiversity and a higher organic matter content in the soil. Therefore, reduced tillage might also benefit the performance of organic agriculture. However, to use reduced tillage techniques in organic agriculture, possible set backs in for example weed pressure, pest and disease pressure, nutrient availability and seed emergence have to be resolved.

Various aspects to overcome these possible set backs are:

a) Total system management for organic reduced tillage production systems
b) Weed prevention and weed control
c) Machinery for green manure and crop residue management
d) Reduced tillage machinery
e) Timing of tillage operations
f) Low compaction machinery/strategies
g) Seed quality and sowing techniques
h) Management of organic fertilisers
i) Knowledge of nutrient dynamics in relation to tillage
j) Variety development
k) Knowledge of agronomic and ecosystem advantages of reduced tillage in organic agriculture

a) Total system management for organic reduced tillage production systems

Large changes in tillage techniques (like from ploughing to non inversion reduced tillage) affect the whole farming system like timing of fertilisation, seeding technique, weed control etc. Important instruments to help this conversion are:

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- Developing and using farmers' craftsmanship, availability of knowledge, participatory learning, communication etc.
- Development of integral strategies including all aspects that are changed because of conversion to reduced tillage

b) Weed prevention and weed control

See also mini-paper on weed control.

- Craftsmanship: There is already quite a lot available in machinery, in knowledge and strategies. Often good craftsmanship is lacking.
- Machinery: Further development of weed control machinery (automats, using ICT, GPS etc) could still help efficient and low cost weed control.
- Knowledge: Also knowledge of mechanical weed control and weed prevention in organic agriculture in the context of reduced tillage strategies is still partly lacking

c) Machinery for green manure and crop residue management

Organic matter, crop residues and green manures stay on top of the soil and may hinder following operations like sowing. Incorporating or reducing them without intensive tillage stays a challenge. There is some machinery available. However not always reliable in all circumstances, not adapted to European circumstances, or insufficient knowledge or experience available for optimal use.

d) Reduced tillage machinery

There are various implements available. But they can still be optimised for different circumstances. For example there are various types of ploughs that are suitable for shallow ploughing (10-18 cm), however there are still problems to use these ploughs under specific circumstances (compacted spots, sandy soils or handling medium to large quantities of crop residues)

e) Timing of tillage operations

The timing of the tillage operations influences the nutrient dynamics in combination with the quality of the incorporated organic matter, weather/climate conditions and soil quality/soil type. A better understanding of these relations is still needed. See also under nutrient dynamics.

f) Low compaction machinery/strategies

Less intensive tillage also means fewer possibilities to solve soil compaction problems. So the strategy should be as much as possible prevention of soil compaction. Current machinery is still, under certain circumstances causing too much compaction. Partly there are solutions available (like seasonal controlled traffic systems, caterpillars, tire pressure, tire size) and new developments can help reducing soil compaction like for example: hovercraft systems, small automated machinery, further developments in harvesting with controlled traffic.

g) Seed quality and sowing techniques

Reduced tillage conditions influence the quality of the seed bed but also the early availability of nutrients and the presence/absence of plant pathogens in the soil. Seed quality, seeding technique and seed rate are instruments to influence seed emergence. For easy emerging crops like cereals, beans etc., direct seeding techniques are available. However for fine seeded crops which need very good germination conditions, seeding technique, seed quality and seed rate under reduced tillage conditions still needs to be improved. Developments in knowledge and machinery are needed.

h) Management of organic fertilisers

Changing tillage management may also need a different quality and application of organic fertilisers. With reduced tillage the fertilisers are so intensely incorporated in the soil as with inversion tillage. Other qualities of organic fertilisers and/or adapted application techniques can help to ensure sufficient nutrient supply to the crop.

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i) Knowledge of nutrient dynamics in relation to tillage

Changing tillage conditions have an influence on the nutrient dynamics. The general rules for nutrient availability under intensive tillage are not the same as under reduced tillage conditions. Experiments show a different pattern in time and per soil layer. Better understanding of nutrients dynamics in relation to soil quality (structure, soil biodiversity, quality of organic matter in the soil) is needed. With this knowledge various aspects as management of organic fertilisers and time of incorporation of organic matter could tune the nutrient availability better to the nutrient demand of the crop.

j) Variety development

Reduced tillage systems in organic agriculture might be more successful if varieties are better adapted to the different soil conditions under reduced tillage like a higher bulk density, other nutrient dynamics, other stratification of the soil.

k) Knowledge of agronomic and ecosystem advantages of reduced tillage in organic agriculture.

Until now limited knowledge has been available of the effects of combination of the organic system approach with the conservation agriculture approach. Theoretical advantages could be in climate adaptation and mitigation, long term soil quality, increase of biodiversity, lower costs etc. There is research on-going in the Tilman Core project. However this FG project will not give the final answer on all agronomic aspects and ecosystem services involved. A more solid substantiation of possible benefits and disadvantages could help farmers to adopt these techniques and policy makers to support them.

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3.1 Insufficient Weed management: Information and communication techniques and mechanical tools

F. Xavier Sans, Schmutz, U and Sukkel, W.

Introduction

Weed management is often the most troublesome technical problem faced by organic farmers in arable crops. Failures in weed management can result in yield reduction and/or extra costs for additional machinery and hand labour. It also has influence on provision of ecosystem services like pollination, pest control, soil amelioration and nutrient recycling, recreational and aesthetic values, to name a few services those weeds can contribute.

The agronomic objective of weed management is reducing weed density to decrease crop yield loss and shifting the composition of weed communities (from undesirable to desirable species) aiming to reduce the amount of damage that a given density of weeds inflicts on a crop. The economic objective of weed management is a positive cost-benefit balance, meaning the weed control benefits (yields but also other ecosystem services) should be higher than the cost of the management strategy. These costs can be direct costs but also indirect costs of using fossil fuels and environmental pollution through greenhouse gases or other side effects (Schmutz *et al*. 2008). However, weeds have an important role in maintaining farmland functional biodiversity (Bàrberi *et al*, 2010; Caballero *et al*., 2010), and this should be balanced with their potential negative impact on agronomic and economic purposes.

In organic farming systems, weed management is based on an integrated combination of tactics that:

(i) Enhance crop/farming system competitiveness and tolerance to weed pressure,
(ii) remove or curtail weed growth in the critical early stages of crop development, and
(iii) reduce the weed seed bank in the soil.

A wide array of preventive, mechanical, cultural and biological methods is available to farmers aiming to control weeds. Overall, farmers commonly keep weeds under control by diversification in the cropping system, based on the correct combination of tillage, crop rotation, cover crop (green manure, dead and/or living mulches) and direct (post-emergence) weed control. Nevertheless, the need for specialisation in a few crops related to market pressure often negatively affects the rotation and as a consequence the agronomic weed management. Furthermore, often farmers have to face to severe weather events and time constraints making weed management more difficult.

While weeds are often one of the biggest problems encountered by farmers during the transition period from conventional to organic agriculture, weeds are is still an obstacle especially for spring crops with a slow early development (i.e. sweet corn, sunflowers, *Brassica* crops) and with low competitiveness (i.e. annual legumes, carrots). While the majority of annual weeds are managed mainly with cultural and mechanical methods, certain perennial weeds (i.e. creeping thistle and broad-leaved dock) are more problematic and research is still needed to provide adequate total strategies (e.g. rod-weeder is very effective after several passes and broadcast blade is also effective if used superficially and frequently).

The incorporation of conservation agriculture techniques (e.g. reduced tillage and green manures) in organic farming systems brings many benefits to the environment and reduces energy use. However, one of the main drawbacks of the use of reduced tillage is the potential increase in weed infestation and shifts in the weed community composition, sometimes to the benefit of more difficult-to-control species, such as perennial and grass species (Peigné *et al*., 2007).

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Practical solutions implemented by farmers and proposals

Practical solutions implemented by European organic farmers depend on the size and specialisation of farms, the level of technological development of the national/regional organic farming sector, their technical skills and the ability to network. Despite significant technological development in the management of weeds in Europe, the use by farmers of southern Europe is still very limited (e.g. Spain). This section aims briefly discussing the most important challenges in future development of knowledge and techniques focusing on scientific and applied research and machinery development for weed management.

i) Enhance crop/farming system competitiveness and tolerance to weed pressure

a) A lot of knowledge is available; however it is not always used. Development of craftsmanship, dissemination, participatory learning, practical guides and tools is an ongoing need. Also EU and international exchange between practicing farmers could help here, especially across EU boarders in farming regions with similar climate and soil conditions (e.g. Brittany and south west England). Translation of knowledge in decision support systems, apps, etc.

b) In addition the development of knowledge and tools still needed. For example, on enhancing predation of weeds/seeds, allopathic effects of cover crops/green manures on weeds, relation of fertilisation and weeds. Effects of crop rotation like grass-clover leys. Effects of crop sequence in the rotational schemes. Effects of intercropping and under sowing on weed control. The use of more competitive crops and locally adapted. Solve conflicts of conservation agriculture strategies with weed control.

(ii) Remove or curtail weed growth in the critical early stages of crop development

a) A lot of knowledge and techniques are available. Timing and daily management is very important. See also previous point i.a. Mechanical weed management has developed innovative tools that are now available and in use by farmers. For large-medium vegetable specialised farms, the choice of using mechanical tools is good and economically sustainable, but for small farms (with less profitable crops) these tools are too expensive. The joint purchase of innovative tools among small neighbouring farmers could help to overcome this problem. However, cooperation from farmers is not easy.

Physical (mulching films) and flame weeding fit to some specific crops (carrots, onions, etc). Mulching can also be done in strips, either with synthetic material or even in weed free compost (e.g. these techniques have been successful in carrots). Recent developments try to fit biodegradable mulching films to silage and maize cultivation, but the cost is still the limiting factor if the value of the crop is low and not relatively high as for sweet corn used as table vegetable. This is however a good example were an expensive arable crop (sweet corn) can support the development of weed control technology which then trickles down and made more cost-efficient so that it is an option to less valuable crops (maize). In addition, these technologies are currently mainly available to large organic vegetable enterprises. For this reason small organic vegetable growers have to develop alternative strategies based on the combination of tactics. In maize the combination of harrowing with the finger weeder could be sufficiently control weeds. In our view weed control for these crops it is more a question of development of craftsmanship and knowledge/sharing experience than available techniques.

b) Development of machines and techniques still can make big progress possible either in effectiveness and or machinery costs (see also section on ICT, GPS, etc), especially in crops with low competiveness (seeded onions, carrots, sugar beets) and/or slow early development. Special attention needed for machinery and techniques for small farms (these must be applied to small-scale, cheap and universal). There are chances for automated weed control robots (like the automated lawn mower). New developments can make these techniques also available and cost effective for small farms. The introduction of cover crops incorporated into the soil (i.e. green manure) or maintained on the soil surface (i.e. dead and/or living mulches) is part of such a strategy. In fact, in the last years, systems that use the roller-crimping technology to terminate cover crops have been receiving increasing interest in resilient cropping system design. The terminated cover crop is at the same time

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used as mulch. However the technique is successful in more continental climate conditions. The first tests in various countries in Europe are very varying in efficacy.

c) Furthermore there are possibilities for the development of machinery for intra-row weed control; sometimes in combination with a strip of mulch (compost, cellulose film, etc)

d) GPS, ICT, sensors and other technologies. Clever combinations of these technologies could strongly improve weed control. Already RTK GPS has made it possible to do the mechanical control closer to the row. There is still large progress possible in the combination of recognition (either by GPS position of by camera/sensor recognition, translation of the information (by ICT) to actuation and improvements in fast and precise actuation. As well as in the precision, speed and costs. There is also a strong development in automated (light) systems. For home gardeners automatic mowers are available. Investments in these developments for agriculture offer possibilities for affordable automated weeders.

(iii) Reduce the weed seed bank in the soil.

a) Tillage: A lot of knowledge on tillage is available. Inversion tillage (ploughing) is an important strategy to reduce the weed seed bank. However ploughing has disadvantages in costs, energy use, soil quality (infiltration, structure, water holding capacity, etc). Minimised, non inversion tillage could have several benefits. However, the problems with higher weed pressure and destruction of green manures should be solved. Soil solarisation and bio-fumigation practices are also helpful in reducing the seed bank.

b) Prevention of seed shedding: The mechanical removal of weed seed heads before seed shedding is an excellent strategy that prevents weed seeds from entering the seed bank.

c) Predation: One form of biological control of weeds is conservation of organisms that consume weeds seeds, and thereby made withdrawals from the weed seed bank. While some decision support systems to prevent weed seed shedding are developed, more scientific and applied research are needed. Similarly, more research is needed to assess the feasibility of weed seed predation and weed seed decay as tools in organic weed management.

d) Prevention of external infestation (manure, compost): Organic residues have to be handling correctly by composting farmyard in avoiding spread weeds across the farm or, if the manure is imported from outside the farm, introduce weeds potentially troublesome.

Balanced combination of strategies i, ii and iii

Disciplinary knowledge is available. But how to combine the different elements in an effective total strategy which is economically viable is a challenge. Knowledge exchange and best practice dissemination using advisors and farmer's networks.

Constraints for further development

1. Low interest to invest from machinery companies (too small market).
2. Limited availability of locally-adapted crop varieties. The market often demands commercial varieties, not well-adapted to organic farming systems. No breeding programmes on this aspect from seed companies.
3. No participatory research where farmers and growers are directly involved and can learn from each other.
4. There is a knowledge transfer problem. However, knowledge transfer is just a part. It's also learning doing, development of craftsmanship, etc.
5. Availability of knowledge ... what knowledge has to be developed?

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4.1 Pest and diseases: Functional bio-diversity

INGER BERTELSEN AND LUISA MANICI

Introduction

By using the term functional biodiversity it is stressed that the increase of biodiversity has a specific purpose. In this paper this purpose is a rise in yield and quality of the crop by increased resilience and a better control of pests and diseases (weed could be included as well). When it comes to pest and diseases, a higher yield should also come through a more stable yield. Control of pest and diseases in organic farming systems is based on suppression of pest and pathogen able to prevent severe attacks of specific pathogenic populations, or single enemy species, by maintaining a balance among their communities. The main component of this balance is biodiversity which, in agriculture, is conventionally identified with crop diversity. However, as also organic farming systems have a certain specialisation level to support competitiveness of their productions (see horticultural production in Mediterranean areas or cereal production in several continental European areas), they should identify the type of biodiversity that is desirable enhance in order to increase yield and quality of their main crops (Altieri, 1999).

Ways to obtain functional biodiversity

Increase in yield through functional biodiversity can take advantage from what is already known in agro-ecology about the interaction among pest and enemies for pest suppression, relationship among pathogens and soil microorganism for increasing soil suppressivenes as well as whole soil functioning. Indeed, cropping systems with rising suppressive ability can be developed by enriching functional diversity according to goals that are gradually identified over time.

Increased yield could be obtained through different approaches to functional biodiversity. More of these are already used by organic farmers.

- **Field scale.** Increasing the biodiversity within the crop e.g. variety mixtures or mixtures of different species. Examples: Variety mixtures in cereals to suppress diseases, faba bean/cereals to suppress aphids in faba beans.
- **Farm scale/cropping system scale.** Increasing the biodiversity within the farm or cropping system scale by using better crop rotation, using pre-crops or noncrop plants as "companion plants" together with the main crop or in the margin of the fields (Balmer et al., 2013).
- **Ecosystem scale.** Increasing the ability for the entire system to suppress severe attacks of specific pests and diseases, by increasing biodiversity in and outside fields (long period effect) (Cardinal et al., 2003; Nielsen and Winding, 2002).

Issues linked to biodiversity increase

Field scale

Innovative useful solutions are already used by organic farmers in field thank to their interest in new options. Therefore, good technical description of practices and of research findings from which they have been inferred, would make it possible to spread among farmers the use of those practices and increase the benefit coming from knowledge of involved biological processes.

For these solutions it is important to include the technical solutions in the fields as well as in processing mixed crop after harvest, to make sure that mixed crops will work all the way through the supply chain. A challenge in the use of mixed crop is the identification of the proportion of the components after harvest e.g. mixture of grain legumes and cereal should be separated if necessary and the proportion of components should be known if it sold/used without separation.

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Farm / cropping system scale

Knowledge about the effect of crop rotation, cover crops, companion crops for controlling pest and pathogens is already widely applied in organic farming, but new approaches and new knowledge could give further results. The cover crops and companion plants are more sparsely described than the main crops and a better description of these in regard of pests and diseases could be a way forward.

Application of interesting findings through innovative agro-techniques at farm scale would be needed. E.g. suppression of a specific pest by introducing new predators through suitable host plants (Balmer et al., 2003); using companion plant to lure pest away from the main crop (a margin of yellow flowered rape around a white flowered rape field); suppression of root fungal pathogens by inserting specific no-host crops in rotation cycles; increase of soil biodiversity and functioning through covers crops or crops selected also on basis of their interaction with soil microorganisms (Martin and Kamoun, 2011) as well as incorporation into the soil of ex-farm organic materials (Watts et al., 2010); etc. As for field scale, the practical / technical aspects of application of these technical options in farm must be taken in consideration as well.

Ecosystem scale

Although many indicators of functional biodiversity have been explored (Nielsen and Winding 2002), most of the existing research does not link increased biodiversity to crop yield. This link has been easiest found in case study concerning the relationship between functional biodiversity and crop in the simple systems or at small scale (field or farm scale), but this is much more difficult when considering the effect of increased biodiversity at cropping system scale. Specific studies show that the conservation of natural enemy species richness sometimes weakens, or has no effect, on biological control; this is due to the complexity of interactions occurring in ecosystems. However, combining evidences it is possible to conclude that the conservation of natural enemy diversity and biological control are compatible goals (Staub et. al., 2008).

One of the challenges in this approach is providing tools to predict the effect of biodiversity changes at ecosystem scale. This goal has not yet been sufficiently pursued even though exists interesting studies on this topic both at ecosystem and farm scale (Niemelä, 2000; Häni et al., 2003). However, complex cropping systems such organic ones, require appropriate indicators of biodiversity as well as prediction tools. Previsional easy-usable models built for evaluating the effect of changes of biodiversity on crop yield and quality in organic farming could be useful. Those tools should help to lead the biodiversity increase and the environmental balances toward improved functionality and, consequently, toward crop yield increase in medium period. This implies actions at regional or national scale, to which should correspond a suitable support at farm scale.

Items for a common strategy to increase suppressiveness

As a large knowledge about the relation among plants-microorganisms and plants-pest as well as their interactions is available thank to findings of many the studies on biological control and agro-ecology published since 2000. This should be transferred at field and farm level through dissemination of new agro-techniques set on the gradually available innovations.

To persuade farmers to increase biodiversity as way to obtain higher yield, prediction tools able to calculate engagement and income at farm scale should be made available. Indeed, some investments to increase suppressiveness at ecosystems level are long-term, and their economic benefit must be clear to farmers. For example, if part of land is used for building up biodiversity in farm, calculation of yield increase obtained must refer to the entire use of land as well as the long term benefit for ecosystem should be quantifiable.

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4.2 Pest and diseases: Biotech problems

LUISA MANICI

The commercial market of bio-pesticides has been expanding significantly since 2000; this trend is further increasing following the adoption by the EU member states of the Directives of European Parliament on the Sustainable Use of Pesticides (EC, No 1107/2009). Several biologically active strains of fungi, mycorrhiza and bacteria have been registered as bio-control agents, but many are also products marketed as plant growth promoters or plant strengtheners. They include mineral fertilisers, organic fertilisers and organic substances, such as humic acids, mostly commercialised as complexes, which are often marketed as suitable for organic farming. Given that there is a dearth of independent scientific publications on effectiveness of those compounds on crops; the adoption by farmers on these commercial products is not always based on experimental evidence, and there is the risk that it can be affected by the commercial promotions of single companies. This, combined with the partial efficacy of some commercial bio-pesticides (Falk et al., 1995; Stockwell and Stack 2007; Nielsen et al., 2008; Gilardi et al., 2013) and the variability of their effectiveness in controlling plant diseases (Guetsky et al., 2001), have increased confusion and it could reduce the general interest of farmers in biological control of plant diseases. Finally, the abovementioned issues might also reduce the farmer's awareness that it is possible to prevent several plant diseases by adopting an integrated management approach based on available knowledge on crop-pathogen interactions.

Pest and pathogens control in organic cropping systems is based on continuous adaptation and adjustment of practices (equipment; natural products; varieties, crop sequence and sowing time, etc.) to prevent infestations or counteract disease development. Such strategy requires continuous evaluation of new technical options suitable for organic management. This support is actually provided only in some Member states or in some specialised growing areas, moreover, in most cases it is under the responsibility of organic farmer associations rather than regional extension centers. Scientific knowledge on interaction among crops, microorganisms and insects provides a well precise base for developing technologies able to take advantage from organisms or plant species inhabiting in the agro-ecosystems (Jacobs et al., 2003; Bergsma-Vlami et al., 2005; Maciá-Vicente et al., 2008; Raaijmakers et al., 2009). The findings of research applied should be steadily transferred to organic producers through extension services with a correct dissemination so that farmers can independently develop innovative cropping practices according to farm size and agro-environmental constraints.

Finally, modeling of pests and pathogens represent one advanced available tool which has been poorly applied to organic farming, probably because it has been conventionally associated to the pesticides up to now. However, as plant richness and wild plant species represent key determinants for organic agro-environments as well as for pest and pathogen spread (Anderson et al., 2004), specific models to predict present and future dynamics of pest and foliar pathogens in organic cropping systems could be powerful tools for system analysis. These tools would be of specific interest with respect to the capability on analysing scenarios of sustainability of the European organic cropping systems under changing meteorological conditions forecasted in short and medium period, 2020-2030 (IPCC, 2007).

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5.1 Variety choice: On-farm breeding and seed production

NADIA RIGUCCI, AIRA SEVRON, VÉRONIQUE CHABLE

Introduction

Today, the seed market mainly offers to organic farmers varieties selected for conventional systems. They have been bred in conditions and practices which are completely different from those of organic agriculture.

During the twentieth century, pure lines and F1 hybrid have become dominant in developed countries in a combination of intensification of agricultural practices and intellectual property regimes. But the limitation of adaptability to the natural environmental impacts of those types of varieties was overcome by inputs. The lack of diversity induces a rapid turn-over of the varieties (Dawson and Goldringer, 2012). Most of the modern varieties are genetically similar and rely on narrow genetic backgrounds, and then breeding programmes are vulnerable in unpredictable environmental changes (Finckh, 2008).

In the 1990s, Participatory Plant Breeding (PPB) projects had been initiated in developing countries by international research institutes to better take into account marginal areas.

In Europe and North American countries, on farm plant breeding and seed production has been organised to solve many kinds of problems of organic and low inputs agricultures: the lack of organic seed, the low efficacy of breeding programmes, lack or ineffectiveness of seed systems. The formal seed system and conventional plant breeding activities cannot take into account:

- the heterogeneous environments which cannot be standardised by input supply,
- the broad diversity of farmers' needs,
- the lack of varieties adapted to the various environments and practices (Desclaux et al, 2012).

At international level, IFOAM promotes four major principles for organic agriculture (Health, Ecology, Fairness and Care). On-farm breeding may re-inforce them by (i) the use of breeding processes that respect the biological characteristics and the integrity of the species (Lammerts and Struik, 2004 and 2005), (ii) the enhancement of local adaptation which sustains the ecological system, (iii) the promotion of a small-scale seed market where trust between operators must be the first rule, and iv) participatory research for healthy seed production and adapted crops and the development of cultivated diversity for future generations (Döring et al, 2012).

Consumers are more and aware of qualities and origin of their products. A few years ago, the biggest rye buyers in Finland decided to buy their organic rye outside EU with cheap prices and offered extremely low price of Finnish rye. This stopped totally farmers growing organic and conventional rye. When consumers found out that their bread was not made of rye grown in Finland they started to demand Finnish rye. (What the consumers in Finland did not know was that the rye was actually from Kazakstan, low standards for workers etc.) The big player tried to cover its foot prints and started a EU/nationally funded association and a project to re-create the rye farming, demanding the farmers to use their hybrid-seed, scientifically proven not to contain nearly any nutrients at all.)

Solutions/possibilities

Historically, crops have been grown as populations which have allowed the diversification of crop varieties, adaptation to contrasting environments and use and maintenance of genetic diversity. These populations are known as "landraces" in the gene banks and thousands are conserved all over the world. They are available for farmers according to the Treaty on genetic resources respecting the farmers' rights. This type of varieties is still cultivated as local varieties or heirlooms in some areas for niche agriculture.

Today, diversity is recognised factor of resilience, robustness and adaptation (Döring et al, 2012).

We cannot dissociate on farm plant breeding and on farm seed production as a population variety evolves continuously. Traditional know-how is linked to on-farm seed production everywhere in the world.

This know-kow has been lost in European countries for all the steps of:

- Breeding populations
- Seed conservation
- Seed borne disease preservation

Experiences of on farm breeding and seed production in Europe

Thus, organic farmers started to meet with researchers and to build the first PPB projects for about 12 years in Europe. Some example:

- Spelt in its different ancient regional varieties, old barley and old naked oat and swidden agriculture rye varieties has been found and are in use in more and more organic farms in Scandinavia. Similar development seems to take place all around Europe. These old varieties, that nobody "keeps or owns", suit normally very well to organic farming. They are often healthier, nutricious and have lower demands for field conditions and make most of the use of the nutrients available in soil.
- In Germany, spring faba bean for organic conditions (Ghaouti et al. 2008),
- In the Netherlands, PPB was also the most efficient strategy to address the needs of organic onion producers because commercial onion breeders select varieties solely for conventional farming (Lammerts van Bueren et al 2005).
- In Portugal, PPB was initiated with two objectives not specifically linked to OA: the conservation of the white maize populations for the traditional bread and the maintenance of evolutionary processes in the farmers' fields, which could be valuable for continuing adaptation to future environmental conditions (Patto et al, 2008).
- In France, PPB began in 2001 in three areas in France: (1) In Brittany (the western part of France) a regional organic umbrella organisation (IBB, Inter Bio Bretagne) and (INRA) have initiated a participatory plant breeding programme for organic cabbages and cauliflowers (Chable et al 2008); (2) In the Mediterranean region in southern France, organic farmers needed varieties of Durum wheat, with the aim to produce grain with sufficient protein content and vitreousness for the pasta process (Desclaux, 2005); (3) Maize and sunflower farmers in south western France had several objectives for breeding, including quality, rusticity and adaptation to dry conditions. The project was led by a local farmers' organisation (AgroBio Périgord), and locally funded by the region. They are also working (in SOLIBAM) with cookers and chef of famous restaurants to find again specific recipes with diversifies maize populations. The question of the maize farmer/breeders is to recover the knowledge of the elders to be able to maintain the quality (mainly protein) of the maize with phenotype indicators.

For each experience, we need to organise on farm experiments:

- Definition of the crop(s), the group of voluntaries (farmers, end-users, gardeners, researchers, consumers...) and request of genetic resources to gene banks or all kinds of plant/seed collectors;

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- Definition of the objectives or not; sometimes, we need first to discover the diversity to better precise the breeding aims
- on farm experimentation and seed multiplication; organisation of crop evaluation and seed conservation

Questions from farmers' experience to get:

- good quality of seed: when exchanging the non-certified seed between farmers there is a threat of spreading unwanted weeds. (E.g. in Finland there is very strict national legislation of wild oats with severe consequences if found on fields. Similar legislation does not seem to exist in other European countries or at least not in such severity of consequences?)
- exchanges between Northern and Southern Europe: areas need their own varieties, or do they? How can different areas from different conditions help each other, is there a possibility?

References

Seed Laws context of today (from SOLIBAM working document):

Seed and propagating materials (S&PM) in Europe are regulated by a list of 12 Council Directives specific for the different crops. Moreover 90 other legal acts govern the seed sector, demonstrating how is fragmented and complex. The main objectives and components of S&PM: registration and certification. All directives emphasis is based on productivity, and the assumption is that uniformity and strict rules will increase productivity.

In 2007 the EU started a project of revision of its seed laws under the umbrella of the better regulation process: (**http://ec.europa.eu/food/plant/plant_propagation_material/review_eu_rules/index_en.htm**).

This revision included a thorough confrontation with the various stakeholders, including farmers, or rather their representatives. Of the new goals to be met by future legislation, we find for the first time the conservation of the environment (with references to organic farming), agricultural biodiversity. After several on-line consultations, questionnaires, interviews and public lectures, the Directorate General of the European Commission in charge of seeds (DG SANCO) had come to the conclusion that the system of public control of seed quality should be maintained but with changes and updates to today's model, conceived in the 60s. Almost everyone involved are opposed to leaving the seed sector at the mercy of the free market, and some - especially the world of organic and family agriculture - had proposed important changes to adapt the legislation to the different agricultural contexts and the new demands of society as a whole.

1. In May 2013 the European commission adopted a package of measures that will change all the system of marketing and control plant propagating materials.
2. The estimation of DG SANCO (the commission in charge of the regulations) is that the package will enter into force in 2016.

Within Farm seed opportunities project, we have provided in 2010 an analysis of the limitations of Conservation varieties regulation.

Within SOLIBAM project, we are preparing documents and participating to working group in order to help the evolution of seed laws. Already, the evolution is about:

a. Different categories are set up: officially certified varieties, varieties with officially recognised description (ORD), heterogeneous material, niche market varieties;
b. For the first time some type of varieties can be put on the market without registration to the national or EU catalogue (niche market);
c. For the first time, the dogma of uniformity is challenged and heterogeneous material can be put on the market;

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d. For the first time, the VCU testing includes organic trials as mandatory for Member states.

Agenda:

- two meetings in European Parliament: autumn 2013 and Spring 2014
- meeting of parliamentary groups: March 2014
- meetings Parliament-Council-Commission: 2014 and 2015
- public campaign for discussion: 2013, 2014 and beginning of 2015

and

- ratification of protocol of Nagoya: end of 2013
- Works on genetic resources in the framework of FAO: 2014 and 2015
- UPOV meeting at Geneva (21/25 October 2013) to take into account farmer-breeders

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5.2 Variety choice: Legal solutions

MARCO LOCATELLI

We can reduce the "yield gap" between organic and conventional farming enhancing the performance, but also increasing the awareness that ORGANIC means HEALTH.

For consumers the organic sector is a guarantee of health and of quality.

Many parameters of food quality are been outclassed, because of transformations of population needs. For example in Europe after the Second World War, the population required high protein diet because of how poverty affected the diet. Now our needs are different. It is important to carefully follow market trends and consumer needs. A lot of European people suffer from food intolerance. It is not the celiac disease but a gluten intolerance. Scientific research about cereals have confirmed that some old varieties, some local varieties and some new ones could ensure more healthy content than the modern varieties and they could satisfy many consumers, they can even start eating bread and pasta again.

Some old varieties, still cultivated as local varieties, may be very appreciated for their health properties (such as polifunctional nutrients). Many new projects, for example in Tuscany, are now promoting typical local products such as "Tuscany bread and pasta" that are produced only using varieties of local cereals. Often typical local products are not made with local varieties. The world of organic farming must pay attention to the strong interest of the food industry for healthy products and it has to try to maintain the couple organic=healthy.

The development of these old varieties is slowed down by these legal rules:

- Inability to enroll in the National Seeds Registry because of their lack of some standards of classification (DUS parameters);
- Difficulty to certify the origin of a varietal product when it comes from an "Old Variety", because often farmers and seed companies do not enroll them in the Conservation Register because of the current rules that restrict the farming and the marketing area. So registering the old varieties in the Conservation Register values only locally value and has no economic usefulness.

Solutions

- Remove the marketing's limit area in the Conservation Register, create the possibility that the production area and marketing area do not coincide;
- Remove in the Conservation Register the restriction of sale of determined quantity of seed;
- Reinforce the Regions' Laws about the system of Conservation seeds and Biodiversity protection. The experience by the Tuscany Region, with its Seed Bank and the "Custodian Farmer" system (that guarantees both conservation and selection of these old varieties), is an aim for development the organic farming;
- The National Seeds Registry "Conservation Varieties" could change its concept and also its name. The new name could be "Biodiversity Varieties register" and its could be reviewed to permit an easier way of marketing old varieties;
- Old varieties are considered nutraceutical food. They can reduce the allergy forms, many intolerances and diseases. Maybe, this opportunity can help the Mix-Farm, particularly in farms areas where the environment and landscape are very important;
- "Nonprofessional farmers" could waive the rules of Conservation Register;
- With public funds encourage research about the organic sector and promote forms of aggregations between farmers to begin activity in the seeds sector;

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- After the registration encourage start up or projects that point to a marketing of seeds that promote the origin and health properties of old varieties;
- It would be useful rethink the "waiver system", so that the Seed Companies could make specific programmes about varieties selection for organic farming;
- Safeguard and appreciate the farming, the marketing and the development of Old Varieties. It can be a good system to help the future of organic production in the European context.

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5.3 Variety choice: Breeding characteristics

BENOIT NEZET

The characteristics of organic varieties, and by extension of organic plant breeding, differ from that of conventional breeding systems and conventional varieties. Only a few varieties have been selected and bred for organic farming. Organic growers have largely depended on cultivars bred for conventional systems. Because of the small market, adaptation to organic agriculture has not received enough priority in conventional breeding programmes until now. The limited area of organic farming will be the bottleneck for economic interest in establishing specific breeding programmes for organic farming systems. In some species such as winter wheat, the choice of varieties available to organic farmers is higher now than it was ten years ago (better access to interesting varieties from European countries). Moreover, it has been demonstrated that diversity within the crop (mix of varieties, population varieties, composite cross populations) show better robustness to biotic and abiotic stress.

In all, organically bred varieties need to be:

- Fertile and able to be propagated under organic soil conditions
- Adapted to organic farm conditions, which means: efficient uptake and use of nutrients and ability to develop mycorrhizal colonisation, good rooting systems, durable tolerance to diseases and pests, weed suppressive ability. For organic breeding programmes, there is interest in maintaining variation within varieties to allow for buffered response to variation in the local environment.

Breeders should respect genetic diversity and species authenticity. Organic plant breeding respects natural crossing of barriers and is based on fertile plants that can establish a viable relationship with the living soil.

What can be done to improve it?

Different solutions have been listed: set up local breeding systems, support smart breeding technics, involve seed companies in the research for adapted materials and to give farmers a role in breeding with on-farm breeding and seed production.

Major difficulties:

Demand for diversity of varieties and within varieties makes investment very difficult for seed companies. And public breeding have up until now had fewer resources to work with. Partnerships with seed companies can be developed, for example, the French Technical Institute for Organic Farming (ITAB) is working with the Lemaire Deffontaines company on wheat selection.

Productivity and quality both have to be maintained. Product quality is as important as productivity in organic breeding.

Breeding Characteristics

1. Agronomic features

(with new agronomic characters)

a. **Tolerance to diseases and pests.** The diversity within varieties is a strategic trait which improves robustness of crops to many kinds of pathogens. Improved resistance can be bred in characteristics. Homogeneous varieties should include tolerance or resistance traits. For example, desirable traits for organic maize seed would include disease and insect resistance. Protein crops: to control soil and seed borne pathogens. A high level of disease resistance is necessary especially with respect to *Fusarium, Septoria, Helminthosporium.* The importance

given to each disease is different due to differences in crop management such as rotation and plant density.
For example, in France, a partnership between INRA and the French Institute for Organic Farming (ITAB) managed breeding programmes for low input systems and organic systems. High disease and lodging resistance, low seeding rate and good response to low level of nutrients (B Rolland, L Fontaine, France).

b. **Drought resistance:** especially for Southern European areas, physiological traits for improving heat tolerance in wheat (specific traits). Varieties for organic farming need a higher stress tolerance to abiotic causes as crop management is conceived to reduce environmental impact as e.g. limitation of irrigation.
c. **Crop yields in organic farming**: acceptable yield level and yield stability are one of the major desired variety traits.
d. **Nutrient uptake and use efficiencies:** low nutrient tolerance and root morphology are important traits to be considered in organic farming, mainly the ability to develop symbiosis relationships with microorganisms in soil.
e. **Germination and vigour** with cereals seeds or corn seeds = early vigour.
f. **Competitiveness against weeds:** weed control by competitive crop stands is an alternative or addition to direct control without extra costs (competition with weeds for nutrients, water and light). One indirect measure to suppress weeds is restriction of light through crop shading. These characteristics are very important for spring crop such as maize. For example, early vigour, crop biomass and allelopathy are three useful traits for enhanced barley and wheat competitiveness against weeds. Plant height and ground cover are one of the most important characteristics related to competitiveness against weeds. As shown, weed suppression can be attributed to an interaction between the series of desirable characteristics.
g. **Plants adapted to local or regional climate and soil,** to the organic cropping system. However, agronomic benefits of breeding local adaptation varies and the definition of "region" vary between crop species. Participatory plant breeding (PPB) is a form of interaction between breeders and farmers and is aimed more on adaptation to local growing conditions, whereas conventional breeding concentrates on varieties suitable for wide growing areas. Participatory plant breeding programmes have been initiated for organic cabbages and cauliflowers in Brittany (V. Chable, INRA, France), see mini paper on "On farm seed production".

2. Grain quality improvement

In order to obtain excellent end-use quality characteristics:

a. **High protein content**
b. **Flour quality or baker quality:** development of a process-related diagnostic of quality of flour and making of dough for an optimised production of bakery products based on eco wheat varieties (Dr Ludger Linnermann, Germany).

Maintaining these characteristics in cultivars is not as easy as it sounds. As previous organic farmers' experiences have clearly shown, some disease appears despite a proved resistance of varieties… The bypassing of disease resistance is often due to the intensive use of successful varieties in the same place.

USING breeding techniques compatible with both the ecological and ethical principles of organic farming (finding non-GM solutions to increase organic seed bank/quality, to encourage mixed cropping, high performing spring sown cereals…). The plant's natural reproductive ability should be retained, thus ensuring the sustainable use of the cultivar. Varieties must be able to adapt easily and independently to organic farming conditions.

A key issue will be the variety registration system, which is not adapted to lines for organic conditions. Few varieties are selected in organic farming, for example: HENDRIX and SKERZZO, both wheat varieties in France. But the seed regulations are evolving and may include more possibilities (see mini paper on "seed regulation").

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6.1 Horizontal: Adaptation to Climate Change

JOZEF TYBURSKI

Example from Central Europe

Introduction

Climate change has affected farmers in Europe. In some regions, the result of climate changes has been negative whereas in others – positive. The main features of those changes are:

- higher temperatures and lower rainfalls,
- growing weather instability – huge variations of temperature and rainfall throughout a year, including growing season,
- extreme weather conditions (drought, cloudburst, hailstorm).

In Central Europe these phenomena are accompanied by shorter winters, less snowy and thus lowering of ground water level and water accumulation for growing season. The scarcity of water reserve and low precipitation when being accompanied by hot weather periods must create new limits:

a) water shortages (crop wilting),
b) periodical too high temperature (higher yield loses via increased crop respiration during nights).

What can be done to mitigate these processes?

The climate change problems affect stronger organic farms as majority of them utilise Less Favourite Areas – especially dry and sandy soils (the best soils are usually exploited in intensive, conventional way). Until now most efforts were directed to prevent water losses – especially via so-called conservation soil tillage (including mulching). In Central Europe some more measures can be taken. First of all the crops can be change to those better adapted to warmer and dryer climate.

Organic grain maize growing in northern Poland

The initial implementations in Poland are promising. The first one was the replacement of traditionally grown cereals (wheat, rye, oats, barley, triticale) by grain maize. Maize responds positively to higher temperatures and is more resistant to periodical water shortages. Moreover, frequent inter-row cultivation enhances the mineralisation rate of FYM (and/or green manures and crop residues) and thus speeds up maize growth.

Another advantage is that maize can be grown on low quality sandy soils of 25-30 points (in a 100 point scale). On organic farms the yields of maize grain are rather high – 7-9 t per ha, while on the same soil one can expect 2-3 t per ha of grain of traditionally grown cereals. It means that the grain yields of maize are 2-4 times higher. Before climate warming and the breeding of new maize varieties adapted to Central European climate, these would not be possible.

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Organic soybean growing in northern Poland

Another successful implementation has been replacement of lupines by soybean. Since the end of the XX century, lupines has been susceptible to anthracnose (Gloesporium sp.) and lupine seed yields dropped from 1.5-2.5 t per ha to 0.3-1.0 t per ha. Even so-called anthracnose tolerant varieties do not yield well (especially on organic farms where no synthetic fungicides are used). In economic terms this yield level is non-acceptable. And on light sandy soils it is impossible to grow peas or horse beans.

The warmer climate and the new soybean varieties made it possible to grow soybean. The positive features of the crop are its resistance to most of diseases and its capability to survival in periods of droughts. So, one can obtain 2 t per ha of soybean on sandy soils. On better soils soybean yields are much higher – 3-4 t per ha.

Conclusion

In general organic farmers should be innovative and they usually are. It would be the wrong strategy to pretend that nothing has changed (to expect climate cooling down to its state of some 30-50 years ago). Therefore farmers should change the traditional vision of farming in Europe – not only they way of reduced soil tillage but also change the range of crops they grow. Otherwise the yielding potential of organic farming will not keep up with conventional farming and the yield gap between organic and conventional systems will be growing.

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6.2 Horizontal: Knowledge generating and sharing

CRISTINA MICHELONI AND MARCO LOCATELLI

Introduction

Organic farming is knowledge intensive and was always characterised as a system that replaces inputs with knowledge (Lockeretz, 1991). Organic farmers are on average less than 10% of the total EU farmers and considering their specialisation (vegetables, orchards, arable, animal breeding etc.) the possibilities to meet and exchange information with colleagues are quite limited. At the same time specialised training and advisory is lacking or is extremely weak in many Member States, since in the last decade public advisory service was progressively dismantled. There are exceptions (i.e. Denmark) that demonstrate how advisory service can play a key role in the development of competitive and sustainable organic systems (ICROFS, 2013).

But the pivotal role of advisory services can become the innovation engine only if the generation and sharing of knowledge fits to the specific farm conditions and farmers need. For that to happen there is the need of a direct and continuous contact between farmers, advisors and researchers in a system that allows knowledge to flow in a circular way and in many directions, so to grant the combination and mutual influence of practical with scientific knowledge. That can become common practice only with a cultural paradigm shift of all the actors, that start with the awareness that practitioners experience has the same value of scientific work and the latest accomplishes its task only when used by farmers.

What is the problem?

The "knowledge problem" can be summarised as follows:

- research produces informations that often cannot become farming practice either because they do not reach farmers either because they cannot be implemented due to technical unfitness. The result in both cases is the non use of the knowledge generated;
- practical experience and empirical knowledge offers valuable solutions that can be further developed by researchers and shared/adapted by other farmers but it often does not go beyond the farm-gate as communication means are lacking.

The result is that available knowledge (practical and scientific) in underused, practitioners are missing support (and that negatively affects their performance) and research projects often do not respond to the sector needs (becoming an inefficient use of public money).

What to do?

There are two main actions that need to be developed: a) to make available knowledge used; b) to generate new knowledge that fits to sector needs.

For a) an European network for the management of knowledge should be established. But it has to be built up starting from local needs and knowledge resources, it has to be practice oriented and "light" in terms of structure and costs.

Practical examples of tools that can be used are available in different regions: learning circles, farmers groups, pilot farms, mobility and practice exchange programs....

For b) a participatory approach in research projects is needed. That will assure relevance of the research work and its applicability and at the same time will speed up knowledge sharing and the exchange between researchers and farmers. Multidisciplinary approach should be included, as organics works (and can be improved) only as a system or as a value chain, but it requires a through

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assessment of each innovation, including economic assessment. In this way it will become possible to develop not only best practices but also best global solutions.

To make a) and b) possible the educational and training framework should be tuned accordingly. It includes education of researchers, farmers and advisors.

A few practical examples:

1) **European network of pilot farms:** commercial farms can play a key role as demonstration or pilot experiences. For example variety testing could be assessed on larger scale (hectares) and for several characteristics, including agronomic fitness, economic value and market interest.
   A European network of commercial farms that are involved in research activity could serve also as knowledge basis for dissemination, education and training, reducing costs and making best use of public money.
   That does not mean that "classical" research in experimental sites are not needed, but it should be accompanied/followed by on-farm practical validation.
2) **Farm schools**: as developed in Scandinavian countries (extended also to stable schools) it contributes to consolidate a farming awareness in young generations but also to the establishment of permanent networks of farmers with similar interests/problems. It is also a cheap and powerful training opportunity for young farmers and advisers.
3) **Participatory research**: it grants that research topics are of interest to practitioners and speeds up the use of research outcomes. It is applied since several years and with good results in the breeding sector, leading to the development of participatory plant breeding techniques. The countries with more experience and useful examples to take into consideration are France (for cereals and brassicas) and Austria (mainly cereals). It is part of an on-going EU research project (www.solibam.eu) on the seed issue but it is also at the basis of research on other agronomic topics. For the approach to be efficient researchers should be trained on the methodology.
4) **Study tours/farm visits**: it is a good tool for topic specific exchange of knowledge that can successfully lead to the establishment of farmers groups and can be the basis for the preparation of a research proposal (with participatory methodology). It was common practice for many years in the past (usually organised by the public extension service) and it was recently successfully implemented in organic on the issue of biodiversity and breeding (Columelle - Leonardo da Vinci project) and on the wine topic (SUSVIT and SUSVIT 2 - two Grundtvig projects). It is an excellent method of integration between researchers, advisers and farmers as they can share the visit experience by peers and elaborate its contents and challenges together.
5) **Farmers groups**: named also study groups. They used to be organised at local level by farmers unions but nowadays they are less frequent. They could be developed in larger networks through social media. They are farmers-driven and can consolidate in permanent networks and include, in specific cases, researchers and/or advisers.
6) **More technological tools**: in the last decade social media and internet tools spread also among farmers. Especially organic farmers or farmers used to be in contact with consumers are getting more and more involved in "food communities", that always have interactive internet instruments such as knowledge hubs. Often the exchange of information does not include many technical issues but probably it will in the development of the tools and, more important, with the growing familiarity with the tool.

What is going on

Valuable recommendations of how to reshape agrifood knowledge systems are reported in the IAASTD report (2009). They are further developed and adapted to the European organic system in the TP organics Implementation action plan
(**http://www.tporganics.eu/upload/TPOrganics_ImplementationActionPlan.pdf**).

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Besides two ongoing research projects are tackling the knowledge issue with specific regard to organic and low input systems: SOLINSA (**www.solinsa.org**) and FARM PATH (**http://www.farmpath.eu/**).

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6.3 Horizontal: Ideas for a new disclosure

MARCO LOCATELLI

In organic farming, perhaps more than conventional farming, the raw materials are identified and are very important for marketing.

Unfortunately, the disclosure in organic farming does not pay attention to this point and farmers do not really seem very interested.

Many initiatives of disclosure are supported by public money, so it is important to change concept.

Ideas for a new disclosure:

1) Keep the experimental plot for its scientific value;

2) Further develop the varietal testing in the open field test units (minimum of 5 hectares) where we can estimate all the technical and economic parameters (varietal, agronomic, mechanical, management, soil fertility, weed control, production and market)

3) Promote experimental proof of species and varieties that can meet, either as a product or as a raw material of a processed product, a strong interest for the consumer and market. For example it could be very interesting to develop variety of cereals that may have healthy content and they can be a good solution to contrast food intolerances affecting the European population.

4) Develop a network of disclosure between organic farming companies in Europe. These farms shouldn't be experimental farms supported by public or private programmes (ie. seed companies that commission the trials). These companies have to operate in a market and must be selected for their innovation and their economic sustainability.

The possible public contribution should intervene only to cover the following costs:

- Willingness to disclose their practices;
- Willingness of the company personnel to communicate their practices to other farmers who visit the company;
- Hospitality and living expenses of delegations of farmers visiting .

The public cost of disclosure would be more effective and thus it would suggest interesting solutions to farmers. The public help should also encourage the creation of a network between these companies that can show not only best practices, but also best global solutions. These companies may also be numerous and may be nominated "Disclosure farms". They can also have more income- multi-functional companies and they should also represent their own areas.

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