Knowing, characterizing and assessing systems of organic crop rotations

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Abstract

The choice of crop rotations in organic stockless cropping systems is the first leverage used to manage technical issues (to maintain soil fertility, to control pest and weeds) and economic issues (to insure income). The RotAB project (French Casdar funding 2008-2010) implemented complementary approaches to better knowing, characterizing and assessing arable crop rotations. Their conception depends on numerous factors such as the types of soil and climate (on which depend the types of crops, yield potential, possibility of mechanical weed control…) or the economic context (existence of outlets and continuity of markets). If nitrogen supply and weed control are the most important agronomic issues of organic farmers in stockless cropping systems, phosphorus availability appears to be the next important issue for soil fertility and system sustainability.

Introduction

The question of the choice of rotations in organic agriculture (OA) arises automatically upon conversion. However, very few studies offer advice that can help farmers in this field. The RotAB project was developed to better understand the rotations performed in or recommended by OA. The working hypothesis is that the choice of rotations in these production systems is key to controlling many problems, especially technical ones (maintaining soil fertility, pest control and in particular weed control) but also economic ones (ensuring an income for farmers). The challenge is even greater for specialized systems of arable crops as they raise the question of long-term sustainability in terms of maintaining soil fertility with little or no external organic inputs.

Material and methods

The objectives of the RotAB project *"Can we design rotations that limit environmental impacts while ensuring the economic viability of the farm?"* were to better understand the rotations practiced by stockless organic farms specialised in cereal production and identify their strengths and weaknesses. The project received French national funding from CASDAR. It ran from January 2008 to December 2010. Different approaches were developed to better understand stockless organic arable cropping systems through (i) the inventory of rotations commonly practiced in France (surveys by region), (ii) the construction of eight test cases representing 11 types of rotations in five regions partners in this project, on the basis of data provided by networks of reference farms and 37 in-depth interviews of organic cereal growers, (iii) networking between five long-term experimental sites testing innovative rotations in organic arable crops.

Results

1. Inventory of rotations practiced in arable crops in France

A simple typology was developed to classify rotations identified in each region examined in France: the presence (or not) of perennial fodder crop in the rotation, % of leguminous, % of hoed crops (hoeing practiced), % of spring crops.

The most striking characteristic is the presence or absence of a perennial fodder crops in the rotation such as alfalfa, clover, sainfoin ... that have many agronomic benefits. These rotations are usually quite long: often more than 7 years, sometimes up to 12 years. Other rotations are shorter, on average 3 to 6 years. The important nitrogen requirements of this second type of cropping systems involve adding fertilizers (improvements, organic fertilizers) that are usually expensive. Succession of winter / spring crops and the presence of hoed crops are generally better respected in these rotations. The "cleaning" approach to weeds

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through effect of perennial fodder crops in the rotation is clearly replaced by increased mechanical interventions and winter/spring crop succession that interrupts the weed cycle. These systems are found mainly in the southern part of France where the possibilities of mechanical weed control are facilitated by the climate.

2. Multi-criteria assessment of rotations

2.1 Comparative analysis of the RotAB test cases: Technical, agronomic, economic and environmental benchmarks

Comparisons were conducted on the gross and net margins in the rotation, on the working time per hectare as well as on energy consumption and greenhouse gas emission.

In summary, it can be said that the local pedoclimatic environment and the economic context greatly affect the economic success of each rotation (yield potential, specific opportunities). The analysis of net margins with subsidies, ranging between 220 €/ha and 730 €/ha, does not draw clear conclusions as to the comparative profitability of long or short rotations. However, in the test cases studied long rotations with alfalfa appear to be less sensitive to changes in the selling price or purchase price of inputs. This type of rotation has other advantages as well such as a shorter working time per hectare (if the alfalfa harvest is done by service provision, the cost is offset by recovery at marketing), less dependence on nitrogen across the rotation or easier weed control. However, the inclusion of alfalfa in the rotation remains extremely dependent on the existence of markets and therefore on the local context.

The test cases were also used to analyze the effect of the place of lucrative crops such as bread wheat in the crop rotation. It is thus clear that the cost of production of a wheat following alfafa (<200 €/t) is much lower than the cost of a wheat following faba bean (250 €/t) or rapeseed (275 €/t), although yields are higher (4.8 versus 4.5 and 4.3 t/ha). This underlines the importance of calculating not only the margins and costs of the crop, but of the entire rotation as the results of each crop balances out on the whole.

2.2 Multi-criteria assessment of rotations: technical, agronomic, economic and environmental strengths and limitations

A multi-criteria assessment through the aggregation of indicators was conducted in addition to the analysis of test cases. The MASC model was adapted to the organic arable cropping systems, and more specifically an agronomic decision tree was developed, which led to the elaboration of the MASC-OF model (Carof *et al*, 2012). MASC-OF was applied to 8 test cases/11 types of rotations from the RotAB project as well as 44 cropping systems from the Midi-Pyrenees, a cereal-producing region in the southwest of France (CitodAB project). The multi-criteria assessment conducted in this manner highlighted well the strengths and weaknesses of the systems examined (Colomb *et al*, 2012). Economic sustainability is the least well-maintained dimension over time as it is sensitive to climatic hazards (irrigators limit this factor) and it is dependent on changes in market prices. The social acceptability scores are very good. Maintaining the productive potential is variable based on the system: if overall control of pests and diseases is not a major problem, weed control appears more efficient in systems with alfalfa. Maintaining soil fertility appears highly variable and related to the presence of alfalfa, green manure or the level of efficiency of organic nitrogen inputs (therefore linked to climatic and soil conditions). In the Midi-Pyrenees region fertility management appears problematic because of the high proportion of rotations with a negative phosphorus balance. Finally, the preservation of the environment is the best-assured dimension of sustainability. However, some reservations must be noted on some relatively intensive rotations, consuming high levels of energy and water.

3. Networking between 5 long-term experimental sites in organic stockless systems

In methodological terms, networking between experimental sites helped to build a common toolkit to monitor soil fertility, a key issue for stockless farming systems. In addition, the collective approach (researchers in charge of the experiments, technical advisors and neighbouring organic famers associated to the process) applied to the questions raised on each site allowed to make progress on the design of the systems studied.

In terms of results, the networking aimed at sharing the references acquired on the evolution of soil fertility. The balance of nutrients (phosphorus, potassium and magnesium) was calculated and compared with the evolution of the levels observed in the soil. Levels of organic matter were also monitored. The most striking result was obtained for phosphorus for which the balance sheets plunge drastically: a relative decrease of 10% in content can be achieved by year of cultivation, the lowest levels (15 ppm of P Olsen) reaching levels generally considered critical in conventional agriculture. In other words, coming second after nitrogen, phosphorus can become a major limiting factor of performance in stockless arable cropping systems.

Discussion

Crop rotations depend on many factors

It has become clear that the two major agronomic concerns of producers are the nitrogen supply of plants and weed control that partially determines the choice of crop rotation. Management of nitrogen supply is carried out in part through the introduction of sufficient proportions of leguminous in the rotation (30% to 55% which is far superior to conventional systems). Weed control generally involves lengthening the rotation with a leguminous fodder plant for 2 to 3 years in the rotation or, if the weather permits (and/ or if irrigation is available), by planting hoed summer crops.

In economic terms the profitability of production systems studied appears ensured. However, it is dependent on the selling price to which the current context is rather favourable. The production context has a stronger influence on the profitability observed than the type of rotation. Indeed, on one hand, the pedoclimatic context determines the cultivable species, yield potential and opportunities for mechanical weed control. On the other hand, the presence of local markets strongly influences the choice of crops, by either allowing or not allowing cost recovery. The choice of crops is also influenced by social factors, especially the availability of labour that can be limiting especially during peak seasons.

From an environmental perspective overall a good contribution to the preservation of the environment can be observed. It is important to monitor levels of energy consumption, which vary according to the type of systems. Regardless of the indicators (biodiversity, energy, water...) methodological improvements are expected to better assess and discriminate systems.

Finally, it appears that the sustainability of agricultural systems is a central goal in OA, in particular concerning weed management and the maintenance of soil fertility. The introduction of forage legumes such as alfalfa provides an interesting response whenever it is possible. If the question of nitrogen supply is central to specialized organic arable crops, the study of the evolution of fertility on experimental sites of the RotAB network confirmed by the multi-criteria analysis of farms in the Midi-Pyrenees (CitodAB project) questions the availability of phosphorus in the medium and long term. The strong use of alfalfa also raises questions about the evolution of the soil's potassium content given the strong loss in this nutrient associated with this crop (dehydrated alfalfa or alfalfa hay).

Conclusion

The different approaches of knowledge, characterization and evaluation of arable cropping systems practiced in OA developed in the RotAB project are converging on the findings. The choice of the crop rotation has a strong impact on agronomic issues (especially nitrogen supply and weed control) and economic results. The role of leguminous plants in the crop rotation appears to be very important. Still, more studies should be implemented to assess their precise impact (agronomic, economic and environmental impact), and take into account disease risk that may rise.

Following this project the RotAB network has grown and continues its work: the number of sites increased from 5 to 12; the main themes currently explored are weeds and the problem of phosphorus (role of mycorrhizae) also associated with the multi-criteria assessment of the economic and environmental sustainability (particularly in terms of energy consumption) of these innovative cropping systems.

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