Optimizing and promoting mechanical weed control in arable crops

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Abstract

Within an overall strategy of weed flora management, mechanical weed control practices are complementary solutions to agronomic levers (crop rotation, tillage...) in weed control. Acquiring knowledge and communicating on the efficiency of mechanical practices and tools appear essential. The "Mechanical Weed Control" project in France conducted between 2009 and 2012 made progress in this regard. The project shows that complementary research activities are to be continued (experimentation, analysis of practices) and should be complemented by promotion that focuses on participatory approaches where farmers are involved in the implementation of these new practices.

Introduction

Managing the weed flora is a major concern of agricultural production systems, particularly in the case of arable crops in organic agriculture (OA), where along with the preservation of soil fertility it constitutes the main problem cited by organic farmers. Control of the weed flora is based on a combination of agronomic solutions (crop rotation, tillage...) and mechanical solutions. The study of mechanical weed control practices (tools, implementing conditions...) and their evaluation (efficiency, cost, working time, environmental impacts...) are a prerequisite for a broad dissemination to farmers. The French project "Mechanical Weed control" (January 2009 - March 2012, CASDAR national funding) was set up to study, promote and optimize mechanical weed control on a technical level. An original feature of the project was to promote knowledge transfer from OA to conventional sector.

Material and methods

The objectives of the project were to (i) Obtain information on mechanical weed control practices used by farmers and evaluate the efficiency of these practices, (ii) Gain more knowledge about weeds to better control them, (iii) Study the conditions for transferring these technologies to farmers who are not applying them. Different, complementary approaches were applied to meet the project's objectives:

- Nearly 200 surveys of farmers practicing mechanical weed control were conducted in 7 regions in France (characterized predominantly by cereal or mixed farming). The descriptive analysis of the data revealed some information on the equipment used and the weeds considered to be the most problematic, and it also helped to identify sources of information used by farmers on mechanical weed control (Fontaine *et al.* 2010). 31 in-depth interviews were subsequently conducted to analyze precisely the mechanical weed control plan for main crops (including soil management through inter-cropping and mechanical weed control operations in the crops). Each weed control plan is defined by the objectives of the farmer and rules for decisions-making that enable the achievement of objectives, each one being evaluated according to calculations of technical, economic and environmental indicators.
- Field experiments: the results of mechanical weed control trials in winter cereals in OA were grouped (they constituted the most prevalent crops) and a synthesis was produced of 91 data (number of trials x conditions tested x weed types studied).
- Sociological studies were carried out at the level of catchment areas to assess the responsiveness of farmers on the acceptance of new practices. Two studies were conducted in western France in areas where water pollution originating from agriculture is a concern (Thareau, 2010, Lemarié, 2012).

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Results

1. Knowing and evaluating mechanical weed control practices

The survey results show a clear dominance of the use of the chain harrow and the hoe among organic farmers (respectively 90% and 79% of farmers surveyed use them). The rotary cultivator follows close behind (24% of use), its appearance being a recent phenomenon in many areas. In mixed farming the harrow is an essential tool (96% of use against 68% for the hoe). In cereal production systems the harrow and the hoe are used equally. In terms of the combination of tools nearly 80% of farms in OA employ two or three tools. The chain harrow/hoe combination is used in one out of two cases in all regions surveyed. The presence of three tools harrow/cultivator/hoe is used in 15% to 25% of organic farms according to the region with a dominant presence in specialized arable cropping systems. It is to be noted that a quarter of farms in mixed farming use only the chain harrow, certainly related to the presence of grasslands in rotations, that facilitate weed control.

The analysis of the results of interviews conducted with thirty organic farmers showed great variability in the mechanical weeding control plan (management of inter-cropping + direct weed control in crops). It actually depends on periods of crop establishment and row spacing, favourable weather and soil conditions for intervention, crop rotation and the intervention level by the farmer. For example, in the case of winter cereals, the average values are 6.5 runs per plot, 45 l/ha of fuel consumption and 2.5 hours of work, but they hide very large disparities. Not surprisingly, the mechanical weed control plan that requires more working time and more fuel consumption are those with the highest number of runs: spring crops, especially those with wider row spacing (potato, sunflower, corn).

It is worth to consider the results one by one as they reveal important information. The main weed control plans were reexamined and described in detail (decision-making rules, triggers of interventions, technical, economic and environmental indicators) in a brochure on mechanical weed control for each crop examined (ITAB, 2012a).

Analysis of results of weed control trials for winter cereals shows that the most effective strategies are those with multiple runs, beginning with an early run (between pre-crop emergence and the 3-leaf stage) with an average efficiency of 40%-50% (expressed as % of weed suppression). However, there is considerable variability in efficiencies depending on weed stages and the repetition of runs. However, when the hoe is the predominant tool in strategies used (with multiple runs) they are more efficient (ranging from 40% to 65%) (as shown by Davies *et al.*, 2002). In addition, the later the first run of weed control is conducted the more limited the efficiency will be. The strategies that include early runs and multiple runs appear to be the most effective.

In the trials analyzed average yields increased by 20%-80% compared to the unweeded control. In the trial conditions analyzed, the best strategies were obtained when there were at least two runs with hoes. In contrast, strategies based solely on the chain harrow and/or rotary cultivator appear less efficient. Two hypotheses can be advanced in this respect: (i) the implementation of hoeing, more effective on weeds, limits weed density as well as weed competition over the crop resulting in improved yield; (ii) the use of the hoe accelerates the mineralization of nitrogen, the crop can therefore benefit through improved yield. A combination of these two assumptions is likely.

2. Knowing weeds to better control them

In terms of the weeds considered to be of most concern, the species most cited by organic farmers in surveys conducted in 2009 are the dock (*Rumex crispus, Rumex obtusifolius*) and the thistle (*Cirsium arvense*) (respectively 90 and 86 citations out of a total of 700 citations) with a significant tendency for stagnation. Wild oats (*Avena fatua*) follow behind (54 citations) characterized by a sharp increase in recent years according to farmers affected (55% of respondents indicate a rising trend). No weed is mentioned to be decreasing in the plots, all are estimated mainly to stagnate or even to increase, for instance in the case of vetch. If we examine in more detail the cropping system, both farmers in mixed farming and cereal growers consider perennial weeds to be of greatest concern. Nevertheless, cereal growers more frequently mention thistle, while dock is more prevalent in mixed farming. Grasses (wild oat in particular) are of more concern to cereal growers (28% of farms) than to their colleagues who combine crops and livestock (16% of farms).

In order to help farmers better identify weeds present on their land and especially to manage them over time a brochure was developed in the project. It focuses on the knowledge and control of weeds in arable crops without herbicide use (ITAB, 2012b): it contains a description (elements of biology) of the main weeds

encountered in these systems, photographs are reproduced for ease of recognition and recommendations are made to help control weed development.

3. Disseminating and transferring mechanical weed control techniques

The 195 surveys conducted in 2009 provided some insight about farmers' views on information available on mechanical weed, showing a clear difference between the 157 organic farmers (48% of them do not feel sufficiently informed) and 36 conventional (71% feel adequatly informed) even though paradoxically, this type of weed control is much more prevalent in the first group. In OA the information need on weed control indicated by farmers equally concerns (i) the effectiveness of control methods, (ii) the characteristics of weeds (biology, harmfulness / tolerance), (iii) knowledge of tools. In conventional agriculture a large number of farmers are concerned about (i) the effectiveness of control methods and (ii) cost. The survey also showed that in the survey sample more than one third of organic farmers rely on information obtained from exchanges with other farmers, whereas in conventional the primary sources of information used are agricultural advisors (1/3 of respondents) followed by the agricultural press (27% of responses). It is interesting to note the contrast between the two modes of production and the fact that organic farmers stress the importance of exchanges between farmers as well as the need to have a better knowledge of weeds in order to better control them.

Sociological studies conducted in 2009 and 2011 on territories where water is a major issue show that environmental and health issues are now generally taken into account by farmers. However, mechanical weed control is clearly challenged by the solution that is more accessible to conventional farmers – namely to reduce the dose of chemical herbicides. The working time allocated to mechanical solutions constitutes an important obstacle, more so than a fear of lack of technical efficiency. The provision of practical technical information is important in addressing reluctance: efficiency of practices, work conditions, comparative evaluation of estimated working time and environmental impact. In addition, subsidies granted for such practices often act as triggers. Accompanying the farmer (individually, in group) is therefore critical to ensuring the gradual appropriation of mechanical weeding techniques. Exchange - and hence the organization of these exchanges - between practitioners of mechanical weeding is a key element for enhancing the dissemination of these practices.

Discussion

The different actions conducted in the project have pointed out the need expressed (1) for information, to help change the perceptions about mechanical weeding of farmers who are not (yet) practicing it; and (2) for references on mechanical weed control, to improve practices in terms of technical efficiency, working time, environmental impact, economic cost. The pursuit of field experiments and analysis of farming practices is to be carried out to meet expectations. Knowledge of weeds, the existence of improved tools and settings are other essential components.

Taking into account the expectations of farmers is essential for orienting future research. In addition, integrating their knowledge is also important and can be done by involving farmers to a higher degree in experimental programs. The technical details (types of tools and direct weed control plan in a rotation, main weeds targeted) and communication tools, however, have to be developed based on the target groups, for organic farmers on the one hand and for farmers leaning towards reduced herbicide use on the other, as their needs and modes of cultivation differ.

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