O.30 - Consequences of integrated weed management in arable cropping systems on labour organisation at the farm level : evaluation of the feasibility and the economic profitability

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Abstract

Integrated weed management (IWM) in arable cropping systems (CSs) is based on the combination of a range of techniques to disturb the demography of weed populations. The evaluation of the feasibility at the farm scale is one significant criterion to consider for the evaluation of innovative crop protection strategies. A long term experiment has been underway since 2000 in France. The results over the first 6 years demonstrated that IWM-based CSs reduced the use of herbicides while containing weeds satisfactorily. The feasibility of the tested CS prototypes was studied by creating virtual farms and simulating the working organisation at the farm scale over the year, using the farm simulator Equip'Agro. The labour distribution was compared to the time available for the farmer in each decade, (which depended on the number of days favourable for field operations), a consideration of soil type, the inter-annual variability of rain and the soil humidity requirements of each equipment. According to the simulations, working hours were more evenly distributed over the year in IWM-based CSs because of more diversified crops. Both the mechanical weeding operations and the shallow cultivations for the stale seed bed technique were achieved in decades with sufficient working time availability. However, the late sowing of winter cereals (necessary for preventing the emergence of harmful weeds) was apparently difficult to achieve in the less favourable years, because the number of days favourable for sowing decreases at the end of October. The simulations at the farm scale made it possible to estimate the machinery costs and to assess the economic performance of the virtual farms. The results provided significant information about the trade-off between the environmental quality and the economical performance of CSs.

Integrated weed management (IWM) in arable cropping systems is based on the combination of a range of techniques to disturb the lifecycle and the demography of weed populations. The main components of IWM are (i) diversifying crop rotations with a diversified distribution of sowing dates to avoid selecting a weed flora with a marked emergence seasonality, (ii) adapting soil tillage to manage the soil seed bank (possible ploughing to bury seeds at the right depth and at the right period in the cropping system, repeated shallow tillage to stimulate emergence flushes and to destroy young seedlings), (iii) adapting sowing dates to escape the emergence of harmful species, (iv) creating a mulch either in the intercropping period or under the crop canopy to reduce weed emergence and increase the competition environment for emerged weeds, (v) controlling weeds mechanically using specific implements (hoes, weed harrows, rotary hoes etc). As each individual technique is expected to have only limited effects as compared to the efficiency of herbicides, the combination of multiple control measures is necessary to reach the objectives of both reducing the reliance on herbicides and containing weeds in the long term at density levels with no significant impact on crop yields.

Therefore, shifting from current cropping systems with heavy use of herbicides to IWM-based cropping systems might imply changes in crop management habits and in the farm organisation. The technical feasibility and the consequence for labour organisation are therefore criteria to be considered in the process of evaluating prototypes of IWM-based cropping systems.

A long term cropping system experiment has been conducted since 2000 on the INRA experimental farm in Dijon-Epoisses (France). The objectives of the experiment are to assess the performances of four IWM-based prototypes of cropping systems. The assessment considers a range of criteria,

including the effects on the evolution of the weed community demography, the level of reliance on herbicides, the risk for transfer of herbicide residues in the environment, other environmental risks such as the emission of gas with greenhouse effects (contribution to global warming), the crop production and the economic performances. The four IWM-based prototypes share some IWM principles (for example: diversified crop rotation, adapted sowing dates to escape emergence flushes, competitive crops and competitive cultivars etc), but they differ in some main management options. One system explores IWM as combined with reduced tillage soil management. One system does not include any mechanical weeding during the cropping season, therefore mimicking a farm with no specific tools for mechanical weeding. One extreme system does not use any herbicide. One system is a typical IWM cropping system, with no constraints and allowed to use all the techniques available for weed management (including herbicides if really necessary). The performances of these four IWM-based cropping systems are compared with a standard system corresponding to the current practices of farmers in the area, typically trying to optimise the system for economic profitability. A set of decision rules was defined for each cropping system as a function of the main management options, based on expert knowledge, model simulations and previously published experimental results. Each set of decision rules is implemented on two 2ha fields (two repetitions of each cropping system, i.e. 10 fields and a total area of about 20ha).

The reliance on herbicide in the IWM-based cropping systems was significantly reduced as compared to the standard reference. For example, the Treatment Frequency Index (TFI) calculated for herbicides in the typical IWM system with no constraint was about 60% lower than the reference over the first 6 years, and the amount of applied herbicide active ingredient was about 12 times lower in this typical IWM system as compared to the reference. An analysis of the data of weed community changes over the first 6 years (harvest 2001-harvest 2006) demonstrated a satisfying management of the weeds, as no trend was detected for any increase in the weed density for any species (except a few exceptions) in each IWM-based field (Chikowo *et al*., submitted).

The IWM-based prototypes are tested at the field scale in an experimental farm, which is not representative of real commercial farms. The technical feasibility of those systems in an experimental farm does not mean that they are easy to adopt by local farmers. Therefore, the feasibility in terms of labour organisation at the farm level was studied by simulating virtual farms, using the farming simulator Equip'Agro (Chambre Régionale d'Agriculture de Bourgogne). Ten farms were simulated, corresponding to the 10 fields of the long-term experiment. The area of each farm was 130 ha, and the farmer was supposed to be the sole manpower available for field operations. These features were chosen as a function of the typical farming structures in the Burgundy region. Because the typical crop rotations in the experiment were either 3 years (standard system) or 6 years (IWM-based cropping system), each farm was divided into 6 virtual fields, and each virtual field was supposed to be sown with one of the 6 crops harvested in the corresponding experimental field from 2001 to 2006. This was to account for the fact that a farm with a main cropping system based on a 6-year rotation is likely to grow all the 6 crops every year over the farm area. The equipment of each virtual farm was defined as a function of the equipment used in the experiment for running the cropping systems, but the size and the operating speed was adapted to be consistent with the typical equipment of real farms in the region. The real timing of field operations was used as inputs in the farm simulator, which estimated (i) the total number of operating hours necessary for running the farm, and (ii) the distribution of the labour over the 36 decades (10-day periods) of the year. This distribution was compared to the time available for the farmer in each decade, which depended on the number of hours worked a day and the number of days favourable for doing the different operations, considering the soil type, the inter-annual variability of rain and the specific soil humidity requirements of each equipment.

Some features of the IWM-based cropping systems are likely to improve the labour organisation at the farm scale. The increased diversity of crops is likely to distribute operations more evenly over the year; the number of treatments (herbicides and other pesticides) is reduced; the frequency of ploughing is reduced as compared to the reference which was ploughed every year according to the local habits. On the other hand, some aspects increase the labour requirements. The number of shallow cultivations is increased for implementing both the stale seed bed technique and mechanical weeding. Moreover, the late sowing of winter cereals that is necessary for escaping the autumn emergence of weeds, might be difficult to realise in years with wet conditions at the end of the autumn.

The results of the simulations showed that the total number of working hours in the IWM-based virtual farms was lower or similar than in the standard virtual farms. Working hours were saved in farms with

reduced tillage and in farms not using mechanical weeding. Moreover, the more evenly distributed working plan reduced some work organisation difficulties. In the standard virtual farms, 66 % of the farm area was sown with winter cereals, so that the time available in the beginning of October for sowing might be limiting in some unfavourable years. The area sown with winter cereals was only 50 % in IWM virtual farms, which tended to facilitate the labour organisation. Most of the mechanical weeding was performed during spring time at periods without any time shortage. In the same way, most shallow tillage performed for stimulating weed emergence during the intercrop period did not induce any work organisation problems according to the simulations. On the other hand, in 3 of the 8 IWM virtual farms, the late sowing of winter cereals (after October 25) was apparently difficult to achieve in good conditions, at least in the less favourable years, because the mean number of days favourable for sowing decreases at the end of October. However, delayed sowing is very important in winter cereals to reduce potential weed infestation (and also to reduce the risk for other pests and diseases). Therefore, the tested cropping system prototypes seem to be feasible technically in real farms only if technical solutions are adopted to increase the speed of sowing equipment in order to achieve the sowing of all the winter cereal fields within the few days available after October 25. Moreover, the risk should be accepted by the farmer that the climatic conditions can be so unfavourable in some years that the area drilled with winter wheat should be reduced, replaced by any other spring crop (spring barley for example), but this might have some huge consequences on the agricultural market in the country.

The simulations of working organisation at the farm scale made it possible to estimate the machinery costs and to assess the economic performances of the virtual farms. IWM resulted in significantly reduced pesticide inputs. The machinery costs were slightly increased as compared to the standard reference because of specific equipment and of repeated operations (shallow tillage for example). For some crops, the yield was lower in IWM-based cropping systems, as expected, and the yield was also low in some spring crops introduced in the rotation with the purpose of diversifying the distribution of sowing dates. In the pricing context of the study (year 2006), the reduced inputs did not compensate for the lower yields, and the overall economic performances of IWM virtual farms were lower than the reference farms. These results provide significant information about the trade-off between environmental quality and the economical performance of cropping systems, and should be considered to assess the consequences of future agricultural policies on the fate of agriculture in Europe.

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