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Four years validation of decision support optimising herbicide dose in cereals under Spanish conditions

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ABSTRACT

The Danish decision support system Crop Protection Online (CPO) optimises herbicide weed control. CPO recommends specific herbicide solutions to achieve a required level of control. The aim is to apply herbicides as little as possible but as much as necessary. CPOWeeds is a version of CPO adjusted to conditions in North-eastern Spain. The predicted efficacies and the yield obtained with CPOWeeds were validated in winter cereal field trials from 2010 to 2013. All CPOWeeds treatments were related to the efficacies obtained with standard herbicide treatments decided upon by local advisors. The predictions from CPOWeeds were compared to the actually achieved efficacies in the field trials for the nine weed species at different developmental stages and for 84.2% of the comparisons the obtained efficacies were equal to or higher than predicted. The average difference between predicted and observed efficacies was 2.35 percentage points. Yield was measured in three trials and the recommendations from CPOWeeds were maintaining yield. There were two situations where CPOWeeds were performing suboptimal. One is in the early weed growth stages, as the model is not yet prepared to account for water stress on root action herbicides applied at 10-11 BBCH. The second situation was in fields with a prior unidentified population of resistant *Alopecurus myosuroides*. For key species in winter cereals in Spain, such as *Avena sterilis*, *Lolium rigidum* and *Papaver rhoeas*, CPOWeeds achieved a satisfactory control level. It was concluded that the use of CPOWeeds allowed optimisation of the herbicide application with a very high robustness. The recommendations were satisfactorily for the conditions of the Northeast of Spain and have the potential to decrease the amount of applied herbicides by at least 30%. Therefore, it can be an important tool in Integrated Weed Management.

1. Introduction

Decreasing the dependence on chemical pest control is a primary objective for agricultural legislation and environmental initiatives, based on the experiences from a long period of agricultural intensification. The principle for Plant Protection Products (PPP) application should be as much as necessary, but as little as possible (Rydahl et al., 2009). In practice, however, this is rarely the case. Reality is that advisors often make treatment recommendations for worst case scenarios of each major crop and use these solutions on large areas regardless of the actual weed flora. In order to reduce the applied amount of pesticides the spraying has to be based on specific observations for individual fields. Weed species composition, crop developmental stage and climatic conditions all play a role in the assessment of the optimal spraying solution (Kudsk and Kristensen, 1992; Lundkvist, 1997). For example, glyphosate ED90 for certain species varies between 70 and 1350 g a.i./ha under different treatment conditions (Minkey and Moore, 1996). The potential for dose reductions are large as the label recommended dose has to be efficient under a variety of conditions and it is therefore higher than necessary when optimal conditions prevail.

Decision Support Systems (DSS) play an important role in the selection of optimal PPP's and dosages. Such systems can specify the relevant herbicides and dosages to reflect the actual weed infestation in a field under actual spraying conditions and thus ensure proper weed control. Currently, in Europe, there are 9 DSS for weed control decisions (Rydahl et al., 2009), most of them have demonstrated a potential for reducing inputs within an appropriate crop rotation, while maintaining a high level of weed control.

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Even though, these DSS's have good potentials for reducing herbicide use, there are relatively few farmers and advisors using them in Europe. The two main reasons for the low adoption of DSS are the low incentives to use them due to the relatively low cost of herbicide treatments and the lack of resources or interest by farmers to make weed registrations in individual fields prior to herbicide sprayings (Rydahl et al., 2009). Moreover, farmers prefer high control every year, especially in a crop preceding another in which weed control is more expensive or difficult. By using a DSS they are sometimes advised to accept small amounts of weeds remaining after spraying. Integrated pest management (IPM) is, however, gaining interest and the annex of 2009/128/EU Directive explicitly demands the member states to implement IPM, which imply a decreased reliance on PPPs. Another reason for adoption of a DSS is economical, because despite the low price of PPP's, a reasoned use of pesticides is more efficient than an indiscriminate use.

1.1. CPOWeeds (Crop Protection Online – weeds)

Crop Protection Online (CPO) is a DSS developed and managed by Aarhus University, which was commercialised in 1991 (Rydahl, 2003, 2004; Kudsk, 2008a). CPOWeeds optimises herbicide combinations and dosages in relation to the actual crop and weed infestation either by lowest dose or lowest price. As one herbicide rarely controls all weeds in a field, the model also includes calculation of herbicide mixtures by use of the additive dose model (ADM) (Streibig, 1981).

An important factor in CPOWeeds is the required level of control (target efficacy), which has been decided upon by expert weed scientist and advisors. A 100% control level is not realistic, even with label rates, as some plants will always survive treatment. Furthermore, sublethal doses can inhibit weed plants for a long time after spraying without killing them, thus reducing the weed competitiveness in favour of the crop (Boutin et al., 2000; Terra et al., 2007). Target efficacies in CPOWeeds are estimated based upon densities and growth stages of both crop and weed species. The general principle is that high competitiveness and density of the weed species induces high target efficacies, while the less competitive weed species and low densities calls for lower target efficacies. The aim is to set a target efficacy level, which insures yield and prevent excessive build-up of the soil seed bank, but still enables reduced doses.

In the user-interface eleven criteria are integrated to define the weed scenario in a particular field. These criteria are: season, crop, crop density, potential yield, weed species, phaenological stage and densities of crop and weeds, temperature and water stress. When the user has provided this information the program calculates the level of control required for every species. A herbicide dose model estimates the required dose of the available herbicides and rank them according to either price or herbicide amount. The herbicide dose model contains dose response curves, which are based on experimental data from scientific work and more practical approaches from herbicide efficacy testing. Herbicide resistance is of major concern in weed control and resistant weed biotypes are incorporated in CPO by creating separate weed biotypes with very low sensitivity towards herbicides with the mode of action for which they are resistant.

Different prototypes have been developed since the initial system was launched in Denmark and they have been validated in different crops where the weed coverage at harvest time and the yield was measured (Sonderskov et al., 2014).In the current Danish version, it is estimated that herbicides inputs in cereal crops can be reduced by over 40% without enriching soil seed bank for the succeeding crops.

Presently, CPO is implemented to varying degrees in Norway, Estonia, Poland and Germany in one or more crops. In these countries the validation tests have showed that the recommendations were robust (Sønderskov et al. unpublished results). However, the potential of herbicide reductions varies between countries and depends on the weed species present in the fields and management done to date (Rydahl et al., 2009). Furthermore, an ongoing project develops CPO for weed control in maize in Germany, Italy and Slovenia with a module for mechanical measures included.

1.2. Objectives

The objectives of this study were to validate the concept of CPO under climatic conditions different from northern Europe with a version of CPO developed for the North-east of Spain. The ability to preserve yield and the robustness of the obtained efficacies were validated.

2. Material and methods

2.1. Model description and adjustments made for conditions in the North-east of Spain

The aim of this work was to examine locally generated parameters and adjustments for the dose–response function described in (Rydahl, 2003) with regard to herbicides and weeds present in winter cereal fields in the North-east of Spain. The prototype was developed under the name CPOWeeds.

CPOWeeds is dependent upon parameterisations of dose–response curves for all relevant combinations of herbicides and weed species. Given the amount of existing herbicides and diversity of weed species it is a huge task to provide data for this amount of dose–response curves. Therefore, different approaches were used to collect the data. Dose-response curves were preferably estimated based on field experiments. Ideally, at least four doses, representing different levels of efficacy, should be available for an herbicide in order to establish a dose–response curve. This range of efficacies should be wide enough to estimate all the parameters of the curve accurately For some herbicide-weed species combinations this was not available and the dose–response curves were either based upon less data or borrowed from other European regions. For some herbicides with no existing data, semi-field tests were performed to substitute full field experiments. The available data was scarce for some species, but dose–response curves were estimated for twelve species commonly observed in winter cereal fields in the region, whereof nine was found in the field trials. A safety margin was added to the most uncertain dose–response curves and the higher the uncertainty was the higher safety margin was included for the herbicide efficacy. This was done by shifting the dose–response curve to the right. (Kudsk, 2008b) (Rydahl, 2004) (Rydahl, 2003) Some non-parameterized species were regarded equally susceptible to an herbicide as another species by local experts and similar dose–response curves were adopted in the system for those species.

Target efficacies were established by local expert evaluation (Table 1). Although, at a practical level, only efficacies between 75 and 95% are recommended, lower efficacies were established for research purposes. CPOWeeds listed all possible solutions for a given weed composition in specific fields sorted by Treatment Frequency Index (TFI). TFI is a measure of the dose reductions, where TFI of 1 equals label rate and lower TFI indicates dose reductions.

2.2. Field trials

Two trial setups were conducted from 2010 to 2013. Trials on efficacy were performed over four years, whereas yield trials were all conducted in 2013. Trials were conducted with different types of