Report of the round table
Unifying parameters in mechanical weed control research

Jesper Rasmussen
University of Copenhagen, Faculty of Life Sciences, Department of Agriculture and Ecology, Copenhagen, Denmark

Abstract

This report summarises (i) the introduction given at the initiation of the roundtable discussion about unifying parameters in mechanical weed control and (ii) the following discussion at the EWRS Physical and Cultural Weed Control Group meeting in Zaragoza 2009.

Previous roundtable discussions

Research methodology has always played an important role in the EWRS Physical and Cultural Weed Control Group, and in 2004 the group published a comprehensive guideline paper on research methodology in physical weed control (Vanhala *et al*., 2004). The paper focuses on flame weeding, weed harrowing and intra-row cultivation and it deals with the adjustment and use of mechanical weeders, recording the factors that may have an impact on weeding performance, methods to assess effectiveness, experimental designs and statistical analysis. The aim was to share experiences, to increase the comparability between experiments from different environments and to improve research quality.

The guideline paper does not present a single research agenda but emphasises that high-quality research should be promoted through proper methodology. The underlying assumption was that high-quality research is first and foremost characterized by the appropriateness of the applied methods and not so much by the research content itself. Research content, however, is of primary importance to scientific progress. In other words, an appropriate methodology does not *ipso facto* create scientific progress if the subject matter is trivial.

It is far from simple to decide if research content is crucial or trivial; as with beauty it is all in the eye of the beholder. People who attend the Physical and Cultural Weed Control Group meetings represent diverse backgrounds and interests and do not necessarily share a common perception of good research (Rasmussen, 2004).

Emphasising research objectives

The three roundtable discussions at the Zaragoza-meeting 2009 were each devoted to a specific research objective; the estimation of key parameters in physical and cultural weed control research. The aim of this roundtable discussion about mechanical weed control was to evaluate, whether the working group is mature enough to prioritize future research objectives and whether it can agree on a number of parameters that may facilitate collaboration and progress within future research.

From testing null hypotheses to estimation of meaningful parameters

The introduction to the roundtable discussion was based on the assumption that mechanical weed control can be improved through research and that the evolutionary stage of testing null hypotheses more or less has been passed. It is difficult to envisage that there is much to learn from simple comparisons of qualitative treatments which are subjected to analysis of variance (testing null hypotheses). We are now at the stage where emphasis should be given to quantification of important relationships, and in this context, unifying parameters in mathematical models may play an important role. Such parameters can summarize huge amounts of data and quantify the importance of key factors for the success of mechanical weed control. Key parameters should either fit into decision support models or facilitate the accumulation of basic knowledge.

Definition of a parameter
A parameter is a constant in the equation of a curve that can be varied to yield a family of similar curves. If asked to imagine the graph of the relationship $y = ax^2$, one typically visualizes a range of values of x, but only one value of a. Parameter a can therefore be considered to be a parameter: less variable than the variable x, but less constant than the constant to the power 2. Modified after http://en.wikipedia.org/wiki/Parameter

Parameters hold different qualities depending on the type of mathematical equation (curve) in which they take part, and priority should be given to so-called meaningful parameters, which express features that may be considered biologically important. Polynomial regression should be avoided because parameters hold little meaningful information. In contrast, many exponential functions include interpretive parameters that are easy to understand. For example, the resistance parameter, *b,* presented in Table 1, expresses the relative decline in leaf cover or crop density for each pass with a cultivator. The parameter may easily be converted to percentage decline per pass (Rasmussen *et al*., 2009).

It is an intellectual challenge is to make what is "meaningful" explicit when new parameters are suggested, but discussions about the meaningfulness of new parameters are much more rewarding than discussions of ANOVA tables and treatment means.

Examples

To give an idea about how meaningful parameters may look, three parameters from own research in post-emergence weed harrowing were presented: the parameters of 1) crop resistance, 2) weed control and 3) crop tolerance, which all are parameters in the family of exponential functions. From the crop resistance (*b*) and the weed control (*d*) parameters (Table 1), the selectivity curve can be deduced and calculated as the relationship between weed control (WC) and crop soil cover (CSC) (Rasmussen *et al*., 2008):

$$WC = 100 \cdot \left(1 - \left(1 - \frac{1}{b} \ln \left(1 - \frac{CSC}{100} \right) \right)^{-d} \right)$$

Rasmussen *et al*. (2009) showed how crop recovery can be derived from the crop resistance parameter and the so-called crop tolerance parameter, which expresses how crop yield respond to increasing cultivation intensity in weed-free environments (not shown here).

Examples were given to show that factors like row spacing and crop species influence the parameter values (Rasmussen *et al*., 2008, 2009). The quantification of the importance of these and other factors should be subjected to future research. Finally, it was briefly outlined how the three parameters could be integrated into models with predictive power in order to determine the optimum aggressiveness of cultivation in respect to crop yield.

Table 1. Description of two key parameters in mechanical weed control research

Name	Crop resistance parameter	Weed control parameter
Definition	The ability of the crop to resist cultivation. Assessment shortly after cultivation before recovery takes place.	The decline in weed density immediately after cultivation.
Mathematical notification	Parameter *b* in $L = L_0 \cdot \exp(-b \cdot I)$ The resistance parameter (b) expresses the relative decline rate of L relative to I. L is leaf cover or crop density; L_0 is leaf cover or crop density in untreated plots. I is the cultivation intensity, which could be number of passes.	Parameter *d* in $W = W_0 \cdot \exp(-d \cdot \ln(I+1))$ The weed control parameter (d) expresses the relative decline rate of weed density (W) relative to I. W0 is weed density in untreated plots; I is cultivation intensity, which could be number of passes
Estimation	After transformation of the response linear regression is possible: $\ln(L) = \ln(L_0) - b \cdot I$	After transformation of the weed density and the intensity linear regression is possible $\ln(W) = \ln(W_0) - d \cdot \ln(I+1)$
Other	If L is leaf cover the percentage of crop soil cover (CSC) is calculated as: $CSC = 100 \cdot (1 - \exp(-b \cdot I))$	The percentage of weed control (WC) is calculated as $WC = 100 \cdot (1 - \exp(-d \cdot \ln(I+1)))$
Protocol for experiments and statistics	Rasmussen *et al*. (2008)	Rasmussen *et al*. (2008)

Summarising the roundtable discussions

Among the participants there was consensus that the roundtable should be focused on cultivation with low selectivity, which means post-emergence broadcast cultivation and intra-row cultivation.

Three groups were formed and each group was asked to choose a specific cultivation technique and come up with important parameters, and factors that may influence the parameters. Each parameter should be given a descriptive name. Finally the importance of the proposed parameters should be prioritized and if possible suggestions of experimental designs should be given.

It was decided to use the majority of the allocated time for the roundtable in smaller groups. In plenum, however, it became evident that few were familiar with the concept of "meaningful" parameters, model development and advanced regression analysis. Diverse backgrounds and lack of experience with advanced regression analysis made it difficult to find a common platform for the discussions. In general, the questions raised in the introduction were turned into new questions and there seemed to be more focus on the limitations of the proposed parameter approach than the prospects of the approach. It was obvious that the time was too short for an in-depth discussion of possible benefits of the unifying parameter approach. Reducing the complexity of mechanical weed control into a number of key parameters in mathematical models appeared overwhelming for many participants.

Therefore, all groups more or less created their own agenda for the discussion, and again the roundtable moved into a discussion about different questions related to methodology. The guideline paper from 2004 (Vanhala *et al*., 2004) deals with a number of the raised questions but not all.

The following questions were raised and discussed in the groups:

- Should we use densities, leaf cover or biomass when crop and weed impacts are assessed?
- Mechanical weed control is so complicated that it is often considered an art, how does science cope with this complexity?
- How can we bridge the gab between science and practise?
- How much should we go into plant/crop physiology and other basic disciplines to understand crop and weed responses to cultivation?
- Parameters are important – but do we focus on the right ones?
- Do we always focus on the right responses?
- Do scientists always know what happens in the field when they work with field experiments and what are the implications of too little knowledge about the field work?
- How do different environments (soil type) influence resistance against weeding?
- How important is uprooting versus soil covering of weeds?
- Cultivation before crop emergence – how should it be modelled?
- Why don't we have – or use – standards for crop and weed assessments?

Conclusion

The roundtable was a success if engagement and pointing out of new questions related to research methodology were the criteria. It failed, if the success criterion was an in-depth discussion of key parameters as outlined in the introduction to the roundtable. In retrospect, it may have been too ambitious to expect the roundtable to agree on a number of important parameters and prioritize future research objectives. This would require much more time than was allocated. Even if it is difficult to conclude from the roundtable, there seems to be an agreement that models with meaningful parameters should be given higher priority in future. It is, however, important that protocols for experimental design and statistical procedures are available if parameter estimation should out-compete experiments that are designed to answer whether different treatments give different results.

References

Rasmussen J (2004) Are we making progress in mechanical weed control research? Pages 115-122 in Prodeedings 6th EWRS Workshop on Physical and Cultural Weed Control. Lillehammer, Norway: European Weed Research Society.

Rasmussen J, Bibby B; Schou AP (2008) Investigating the selectivity of weed harrowing with new methods. *Weed Research* **48**, 523-532.

Rasmussen J, Nielsen HH & Gundersen H 2009 Tolerance and selectivity of cereal species and cultivars to postemergence weed harrowing. *Weed Science* **57** (in print).

Vanhala P, Kurstjens DAG, Ascard J, Bertram B, Cloutier DC, Mead A, Raffaelli M, and Rasmussen J (2004) Guidelines for physical weed control research: flame weeding, weed harrowing and intra-row cultivation. Pages 208-239 in Prodeedings 6 th EWRS Workshop on Physical and Cultural Weed Control. Lillehammer, Norway: European Weed Research Society.