6th EWRS workshop Physical and Cultural Weed Control, 6-10 March 2004, Lillehammer, Norway

Modelling the effectiveness and selectivity of mechanical weeding

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Abstract

After many years of field experiments with available mechanical weeders, their possibilities and limitations are roughly known. To compensate for the limited selectivity in young sensitive crops, the limited effectiveness on established weeds and limited workability in spells of wet weather, current research emphasises more on the integration of multiple complementary tactics. Combining mechanical weeding with adapted planting times, false seedbeds, flaming, cover crops, tillage and other tactics is expected to increase non-chemical weed control reliability, reduce herbicide use or the need for manual weeding in organic farming.

Choosing appropriate combinations of tactics and mastering them in variable conditions requires considerable knowledge and skill. Models could be useful tools to derive practical guidelines, train farmers in making complex decisions and test how well the interactions between several weed management tactics are understood. Existing population dynamics models generally use fixed values for mechanical weeding effectiveness. Although the effect of varying effectiveness on long-term weed population dynamics could be approximated, these models are probably not sensitive enough to account for interactions between individual control measures. More sensitive approaches need to be developed because mechanical weeding effectiveness is very time-sensitive and highly influenced by environmental conditions and the way cultivations are carried out.

Detailed assessments and common field studies revealed that models should account for within-population variability in weed sensitivity arising from species- and weather-related emergence patterns and larger weeds escaping control. Models should also account for differences in working intensity of the implement as related to type, adjustment and soil conditions. It might as well be desirable to account for weather conditions that influence plant recovery after cultivation. This paper proposes a model to predict the selectivity and effectiveness of mechanical weeding that takes account of these factors and time-dependent phenomena.

The core of the envisioned model is a database containing a large number of crop and weed plants and their individual attributes at various times (e.g. biomass, anchorage force, height, flexibility, type of damage, desiccation status, position, growth stage). Various modules adapt these attributes by simulating continuous dynamic processes (e.g. plant growth, desiccation of uprooted plants), switching plant status at discrete (but individual-dependent) times (e.g. from "seed" into "white thread" and "emerged"), applying empirical relationships (e.g. between plant mass and sensitivity to uprooting), or other state transitions. This framework allows a flexible exchange of modules (e.g. replacing an empirical by a mechanistic model) and including various processes (e.g. competition, seed displacement) without major implications for the data structure.

The prospects of this approach are demonstrated by a dynamic spreadsheet model that links 1) crop and weed emergence patterns in time, 2) assumptions on early growth, 3) empirical species-, soil- and weeder-specific relationships between plant biomass and the probability of being buried and/or uprooted assessed in field experiments, and 4) assumptions on plant mortality resulting from uprooting and growth delay induced by burial. The model predicts weed control and crop damage (both density and biomass reduction) induced by multiple cultivations, accounting for population heterogeneity. If emergence patterns, growth rates and recovery of damaged plants are related to weather conditions, this model could predict effects of cultivation timing. When combined with workability predictions, the model could help assess weather dependency and evaluate solutions to weak spots in weed management systems before testing them in long-term experiments.


WEED RESEARCH
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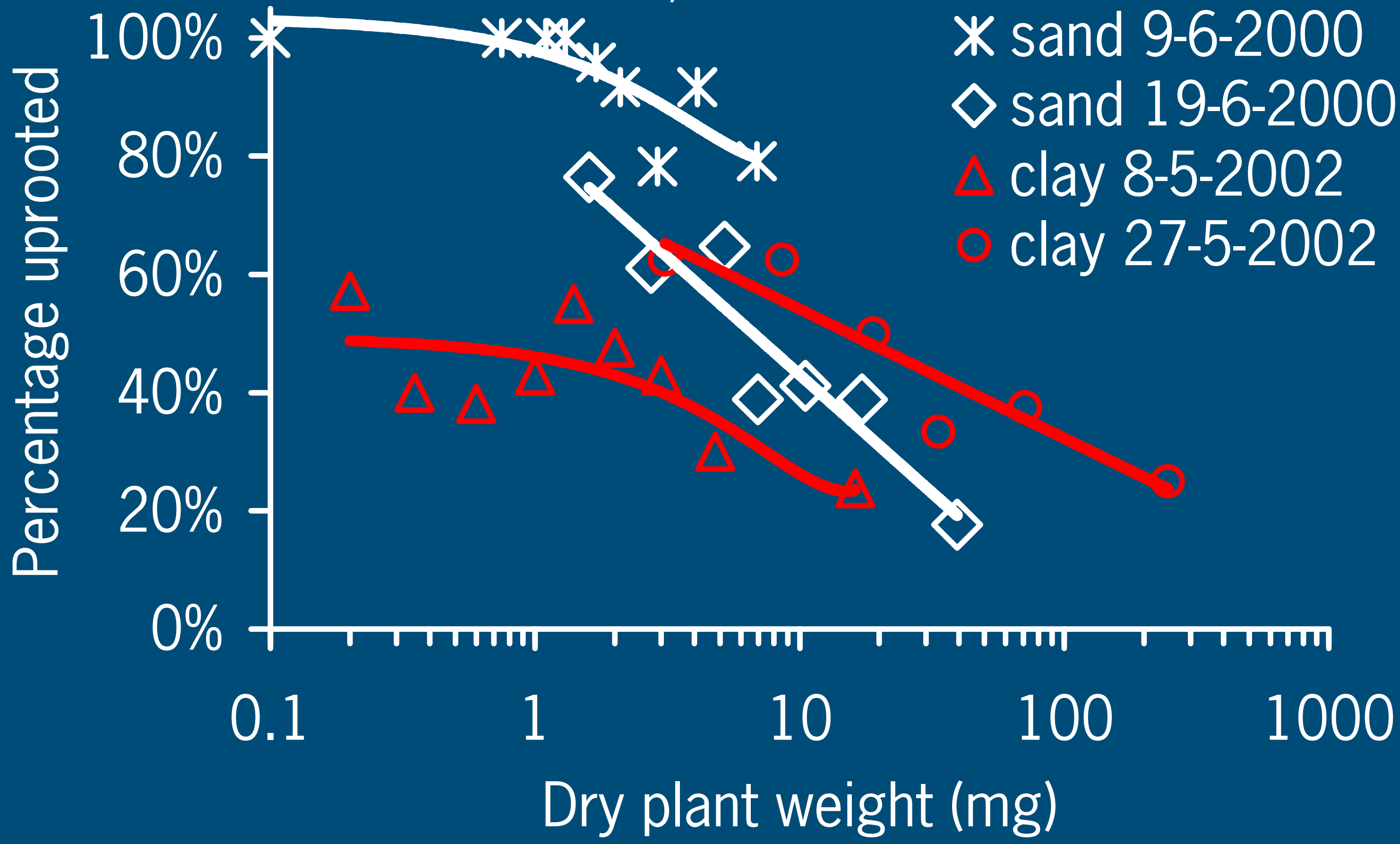
Modelling objectives

- Component for population dynamics models
  - More sensitive weeding effectiveness estimates
- Integrate multiple weeding tactics
  - Mechanical, thermal control and preventive measures
  - Adapt timing and aggressiveness to crop/weed sensitivity
  - Study weather dependency
- Derive relationships affecting weeding selectivity
  - Effects of soil and weather conditions
  - Separate effects of factors → validity
  - Sensitivity analysis / scenario studies

Basis: detailed field measurements protocol

Torsion weeder, *Poa annua* L.



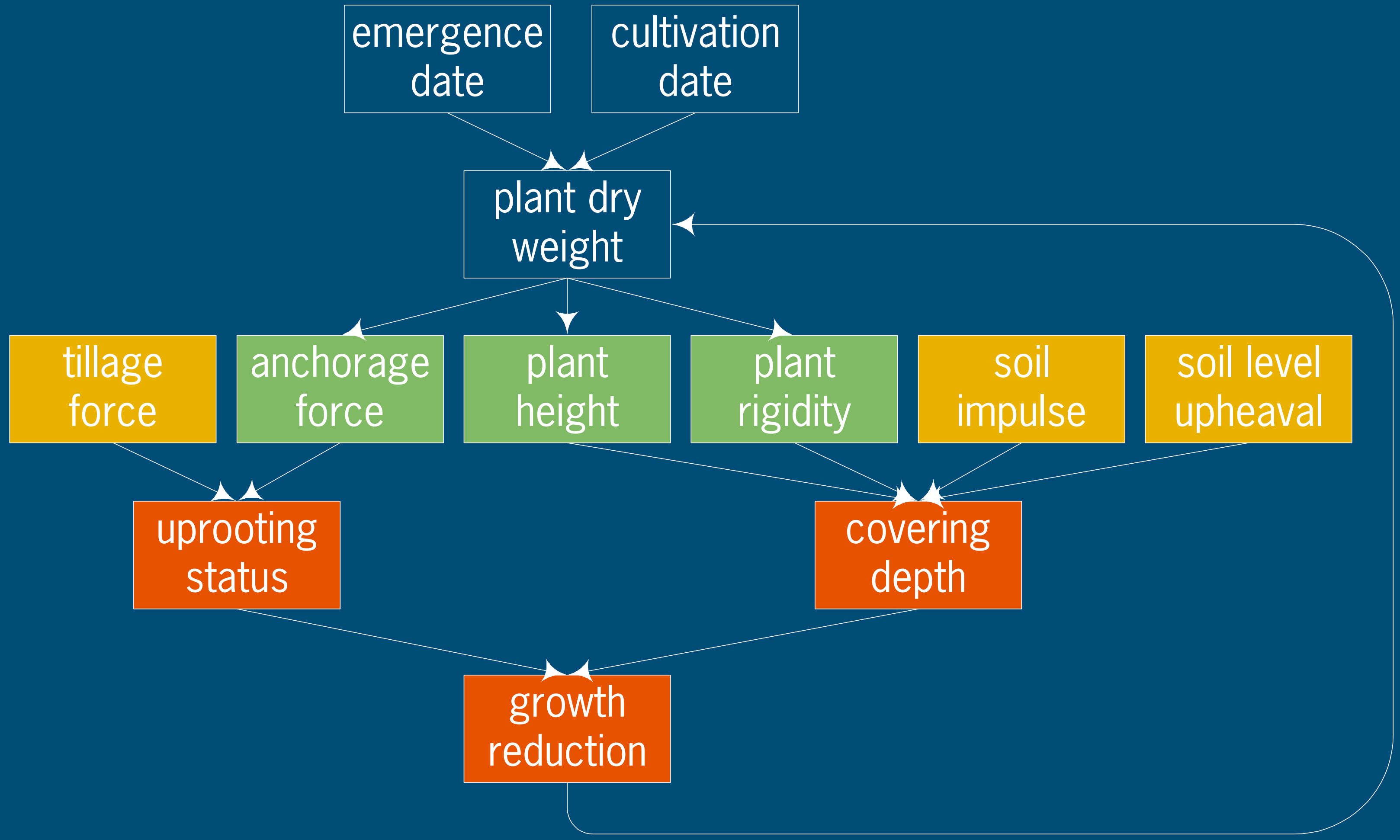
Model should account for…

- Emergence flushes
- Heterogeneous damaging
- Partial control

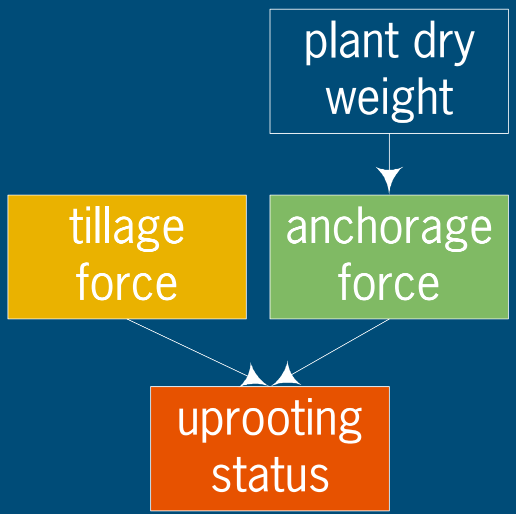
} heterogeneous populations

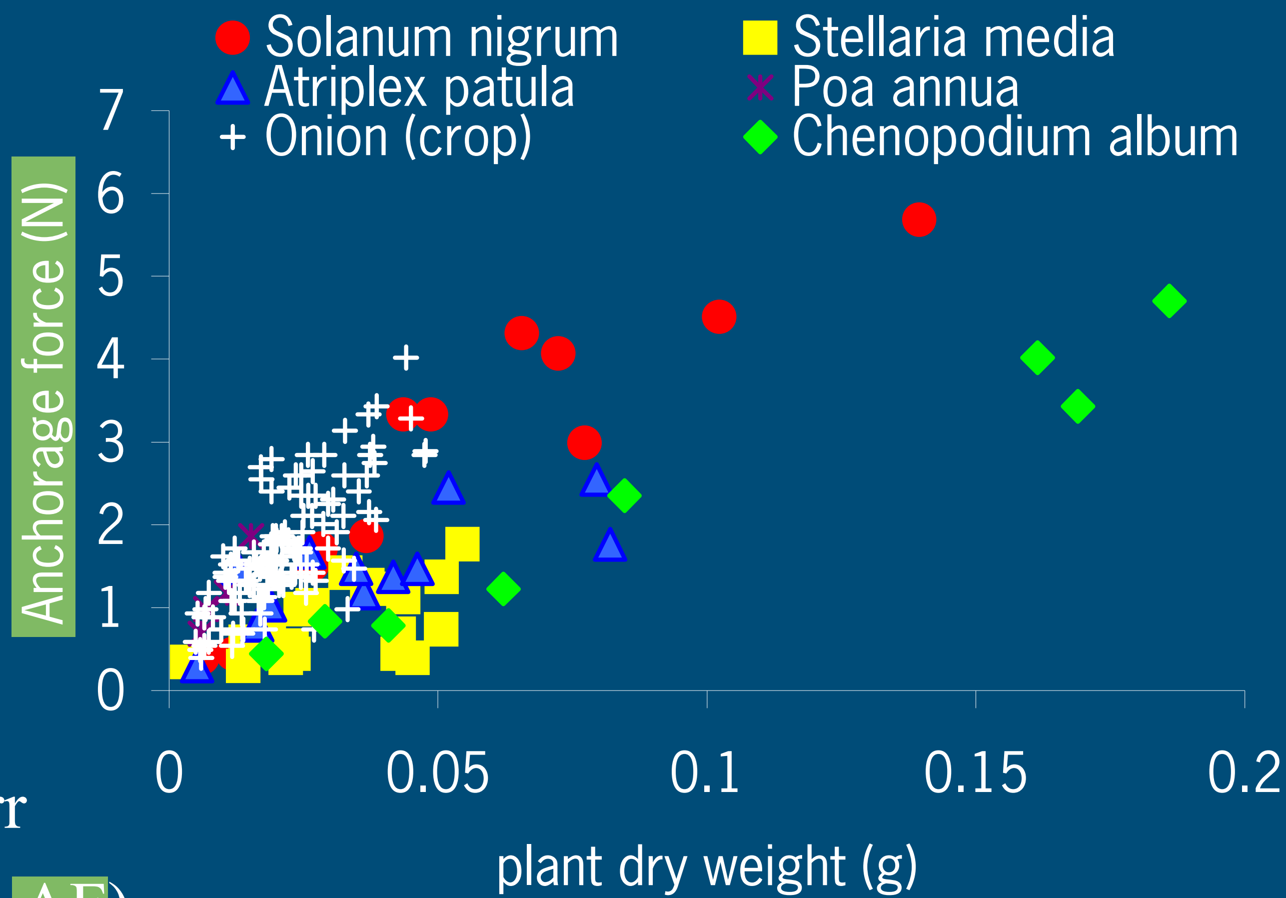
- Weeding aggressiveness and selective ability
  - Tool+adjustments
  - Soil conditions
- Species + plant size → susceptibility to damage
- Species+ damage type → %killed, growth reduction
- Altered crop - weed competition, compensation

Model structure



Uprooting model

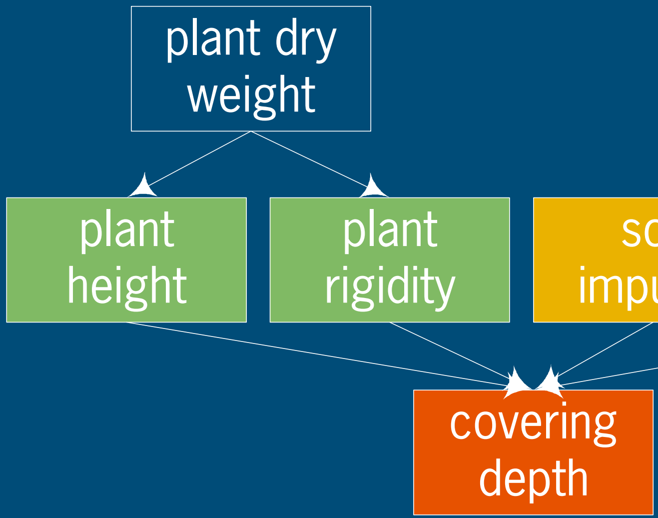


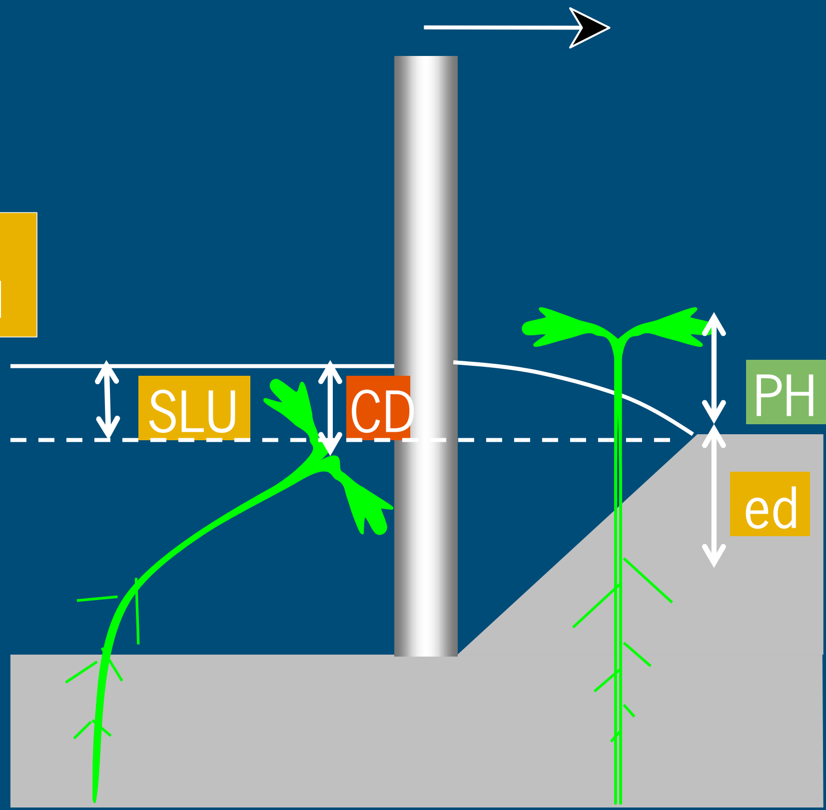


$$AF = a \cdot PDW^{b} + err$$

$$\log it(u) = m \cdot (TF - AF)$$

Covering model





$$PH = f \cdot PDW^{g}$$

$$PR = h + j \cdot PDW^{k}$$

$$CD = -(PH + ed) \cdot \frac{PR}{PR + SI} + ed + SLU$$

Recovery model

Microsoft Excel - simuweedcontrol.xls

Recovery of damaged plants

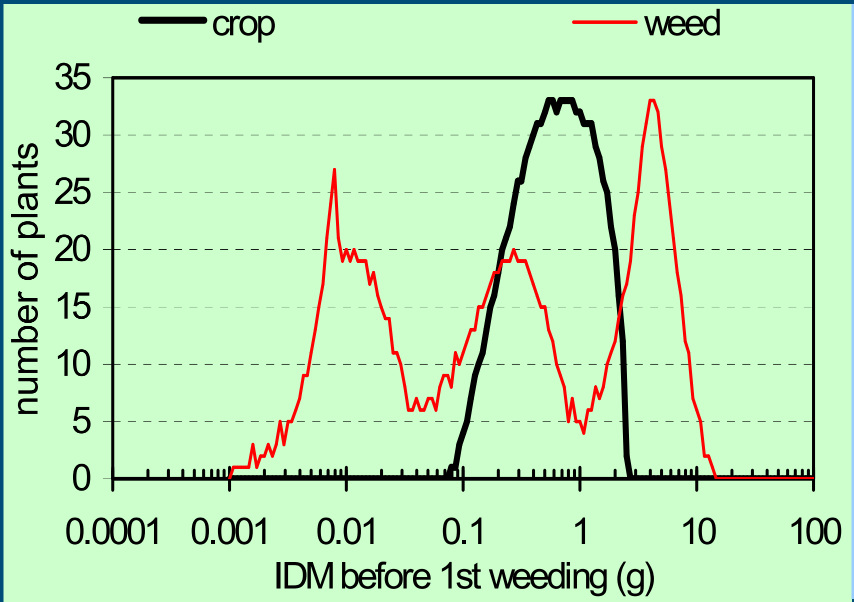
	uprooted		covered		uprooted, covered	
population	mortality	IDM loss	critical depth	max. IDM loss	base mortality	extra IDM loss per mm
crop plant	90%	30%	15	40%	90%	2%
weed plant	60%	30%	15	40%	40%	2%
emerging crop	100%	50%				
emerging weed	100%	0%				

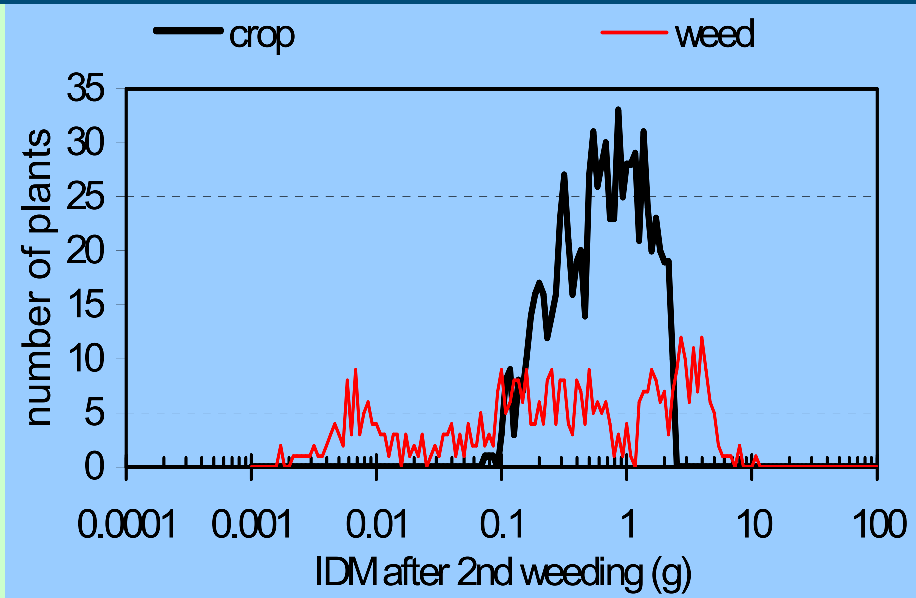
main / distribution / indivdata / histograms / emergencedata / weedingdata

Example of simulation results

Results cultivation 2

population	emergence	uprooted	covered	killed	IDM loss
crop	100%	18%	36%	17%	5%
all weeds	97%	52%	87%	64%	18%





Further "cooking"...

- Include better models
  - Emergence
  - (Early) growth
  - Crop-weed competition
- Develop & test damage models
  - Using existing laboratory data
  - Further field data collection
    - Apparatus to measure anchorage force and plant height
    - Recovery of plants and "white threads"
    - Diverse soil and weather conditions