ENDURE

European Network for Durable Exploitation of crop protection strategies

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Thematic Priority 5

FOOD and Quality and Safety

Deliverable DR4.5

Database of traits influencing the dynamics, distribution and competitiveness of weeds in Europe

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Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)	
Dissemination Level	
PU Public	**X**
PP Restricted to other programme participants (including the Commission Services)	
RE Restricted to a group specified by the consortium (including the Commission Services)	
CO Confidential, only for members of the consortium (including the Commission Services)	

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Summary

The project has been successful in establishing a well-functioning team working on trait-based analysis and modelling of weeds. Its first major output, the Weed Traits Database (WTDB) has been delivered according to plans and is accessible on Internet. The prospects are good for (1) attracting further research funding, (2) generating international interest and (3) using the research tools developed by the group to generate the knowledge, necessary for improving the current weed management practices throughout Europe.

1. Activities

1.1. Workshops

During the first 18 months three workshops were held with increasing attendance.

Table showing the number of workshop participants, and the number of ENDURE and ex-ENDURE institutions thus represented.

Venue	Participants	ENDURE institutions	Extra-ENDURE institutions*
AU, Denmark, 25-27 April 2007	8	5	1
SZIE, Hungary, 4-5 December 2007	9	7	0
SSSUP, Italy, 13-16 May 2008.	16	8	2

* University of Iowa-Ames, University of Maine, University of Wisconsin.

1.2. Project practices

The practices of the project have been laid out by the project leader to facilitate openness, creativity, transparency and common project ownership, while maintaining intellectual property rights.

These practices are being facilitated by the project leader Niels Holst (AU).

1.2.1. Openness

From the first workshop there was consensus that

- the activities of the group would be most valuable to ourselves and ENDURE if researchers from extra-ENDURE institutions were invited,
- the scientific outputs of the group should be made openly available to the international scientific community, on Internet as well as in scientific publications.

This standpoint was confirmed at the following two workshops. Material has been sent to IUPDC to align the formal contracts between institutions with this standpoint of the scientists.

The business plan underlying this standpoint is that the activities of the group can only be made long-term sustainable through attraction of national and international research funding; and the more well-known and widespread our work is, the better are our chances to obtain such funding.

An alternative business plan would opt for patenting and manufacturing of saleable products. However, our two products WTDB (the weed traits database) and WeedML (the new language for representing weed models) are research tools with too small a market to make a profit through software sales.

1.2.2. Creativeness

The project team consists of researchers and students embracing both users and developers of WeedML and WTDB. Together we create tools to obtain deeper understanding and work more efficiently, letting weed ecologists focus on weed ecology and software developers focus on software development.

The project works on two tracks in parallel: one is the scientific discussion that is the foundation of WeedML and WTDB, the other is the software engineering process that incarnates WeedML and WTDB in software design and implementation. An endpoint, at which we would consider the job finished, is not envisioned for any of the two tracks.

The scientific discussion track gets most lively at the two yearly workshops arranged by team members, who take turns acting as hosts. The output of the workshops are reflected in updates of WeedML and WTDB documents, describing design decisions and priorities, published on the project web site and ENDURE Collaborative Workspace.

The track of software related to WeedML and WTDB is developed according to the principles and practices of Agile Software Development (www.agilemanifesto.org/). Therefore, users and developers work together as a team, and the workshops are used to brainstorm, define and prioritize user stories (i.e. requirements) to set up a frame for what WeedML and WTDB should and should not include and to guide WeedML and WTDB software development.

1.2.3. Coherence, identity and transparency

For most of the researchers, this project forms a minor part of their project portfolio. They are active only in short bursts, such as when going to a workshop or entering data into WTDB.

To facilitate a coherent working process, a feeling of project identity and secure transparency of current project activities, priorities and results, the project leader decided from the beginning to center all project activities around one dedicated project web site (now at www.weedml.org/).

Whereas the Collaborative Workspace gives the researchers a feeling of being part of a big, many-facetted organism, the project web site emanates a family atmosphere that, while stressing the links to ENDURE, also welcomes project participants from outside ENDURE.

That the Collaborative Workspace and the project web site play these roles has been confirmed by the project participants.

1.2.4. Ownership

The group works on the common understanding that all decisions are to be taken jointly, the foremost forum for discussions being the workshops. This secures that ownership of project priorities is being shared among all project participants, both in reality and as a gut feeling.

1.2.5. Intellectual property rights

The WeedML is an open standard defined by the design documents on the project web site. It can be used for any purpose but, if used in part or as a whole, a reference must be given to 'WeedML: a medium for representation and exchange of weed demographic models. www.weedml.org' to acknowledge the accumulated work of the team. You have the right to develop open source or commercial software to handle WeedML files, as long as the above reference is clearly stated.

The WTDB is an open database found on the project web site. It can be used for any purpose but, if used in part or as a whole, a reference must be given to 'The Weed Traits Database (WTDB). www.weedml.org.' to acknowledge the accumulated work of the team. You have the right to develop open source or commercial software to work with WTDB data, as long as the above reference is clearly stated. This includes the right to extract and embed WTDB data into software.

All academic outputs inspired by or resulting from the activities of the project must have author lists according to the ICMJE Uniform Requirements for Manuscripts (www.icmje.org/).

2. Results

The project will have two results, one is WTDB (the Weed Traits Database) the other is WeedML (a language for weed modelling). This report concerns only the former of these as its delivery is now due. The latter is due 31 December 2009 by the ENDURE milestone: 'New weed management models parameterised and evaluated'.

The development of WTDB went through phases of requirements formulation, design, implementaion, data entry and actual use.

2.1. Weed Traits Database requirements

The requirements for the weed traits database (WTDB) were decided upon at the first workshop in 2007 and presented below.

2.1.1. Usage scenarios

The following usage scenarios describe how WTDB may be used in various environments, and represent a wide range of activities and needs that are representative of the problem space to be addressed. They are intended to be used as design cases during the development of WTDB, and should be reviewed when critical decisions are made.

1 STATISTICAL ANALYSIS

Carry out statistical analyses to explore the relationships between weed traits.

2 FUNCTIONAL GROUPS

Identify functional groups and typical species of each group.

3 INDICATOR TRAITS

Identify indicator traits, i.e. traits that are good indicators to which functional group a species belongs.

4 SIMULATION MODELLING

Access WTDB from a simulation models to look up values for traits and parameter.

5 EXPERIMENTAL DESIGN

Standardise experimental design by rational selection of weed species for experimentation.

6 RESEARCH PLANNING

Identify gaps in knowledge about weed traits and model parameters to aid rational planning of research activities.

7 IDEA GENERATION

Inspire to new scientific perspectives on weed ecology.

8 SCIENTIFIC PUBLICATIONS

Serve as a basis for scientific publications.

9 PUCLIC USAGE

Used by researchers outside the ENDURE RA4.5 Working Group.

2.1.2. General requirements

WTDB must include traits to describe both annual and perennial weed species.

WTDB must be implemented in standard, widely-used database software.

WTDB should not contain the raw data but statistical summaries thereof.

WTDB must reside on the Internet, possibly on an AU server, or maybe INRA.

WTDB may include how management procedures affect traits.

2.1.3. Data model

WTDB must contain metadata to facilitate interpretation of the data.

2.1.4. Functionality

WTDB must have a simple web interface.

WTDB should be accessible through Virtual Lab.

2.1.5. Contents

WTDB should initially focus on 20 weed species deemed important by the ENDURE RA4.5 Group.

To make WTDB as widely applicable as possible, we must consider different growing systems, including organic vs. herbicide-based agriculture, and select a wide range of weeds of importance different crops (cereals, maize, oilseed rape, beet, potato, soybean, vegetable row crops).

2.2. Weed Traits Database design

2.2.1. Technical design

WTDB was implemented as a simple relational database on a Microsoft SQL Server at AU by an AU software developer, who is now a member of the later-formed ENDURE technical team. The prerequisites for transferring WTDB to a common ENDURE server is currently being investigated.

The user interface to WTDB (pvo.planteinfo.dk/wtdb/) is continuously being refined addressing the demands of the users, as discussed and decided upon at the working group's workshops. Eventually, there will be access to WTDB from Virtual Lab.

2.2.2. Species included

A list of species across Europe and across growing systems was formulated at the first workshop and since then slightly edited through consensus. The list includes the species that we concentrate our efforts upon getting described in WTDB, through estimates of key biological traits found in literature, reports or unpublished work.

The species selected for the Weed Traits Database. Names of people refer to the team member list found at www.weedml.org/home/team.html.

Annual broad-leaved species

1 - Abutilon theophrasti (Ivan)
2 - Amaranthus spp. (Eric)
3 - Ambrosia artemisiifolia (Zita)
4 - Beta vulgaris (Nathalie)
5 - Brassica napus (Nathalie)
6 - Centaurea cyanus (Arnd)
7 - Chenopodium album (Ivan)
8 - Datura stramonium (Zita)
9 - Galinsoga parviflora (Denise)
10 - Galium aparine (Niels)
11 - Papaver rhoeas (Zita)
12 - Polygonum spp. (Marleen)
13 - Raphanus raphanistrum (Gionata)
14 - Sinapis arvensis (Federica)
15 - Solanum nigrum (Marleen)
16 - Stellaria media (Jon)
17 - Tripleurospermum inodorum (Zita)

Annual grass species

1 - Alopecurus myosuroides (Nathalie)
2 - Apera spica-venti (Niels)
3 - Avena fatua (Denise)
4 - Bromus sterilis (Arnd)
5 - Echinochloa crus-galli (Zita)
6 - Poa annua (Mette)

Perennial species

1 - Cirsium arvense (Ilse)
2 - Elymus repens (Eric)
3 - Rumex obtusifolius (Jon)
4 - Tussilago farfara (Ilse)

2.2.3. Parameters included

A list of the most important biological traits of weeds, influencing their dynamics, distribution and competitiveness, was formulated at the first workshop. At the following workshops it was edited as we gained experience collecting estimates of the paramers.

Germination parameters included in WTDB

Parameter	Description
GERMCAL[1..12]	Germination calendar containing relative percentage germination for each month totalling 100% for the whole years. Several calendars can exist for the same species; metadata tells for which climate the calendar is typical.
GERMTOT[1..2]	Total percentage germination per year in disturbed [1] and undisturbed [2] soil.
GERMBASE	Base temperature for germination, i.e. lower soil temperature threshold below which no germination happens.
GERMCHILL	Is there a chilling requirement to break primary dormancy? The requirement can be absolute, partial or none.

GERMLIGHT	Is there a light requirement for germination? The requirement can be absolute, partial or none.
GERMDEPTH[1..2]	Soil depth for emergence is given as the optimum [1], i.e. the depth from which maximum emergence was observed, and maximum [2], i.e. the deepest layer from which emergence was observed. If a function was used to summarise the data, the first parameter is the peak of the function and the second, the depth of 1% emergence.

Seed parameters included in WTDB

Parameter	Description
SEEDMASS	Air dried 1000-seed weight in mg.
SEEDCOAT	Percentage of total seed weight made up of non-investing structures (e.g. seed coat, awns, pappus)
SEEDPER[1..2]	Half-life of seedbank in undisturbed [1] and disturbed [2] soil, measured in years, assuming an exponential decay; i.e. if the decay is described by $y=a\cdot\exp(-bx)$ then the half-life is $\ln(2)/b$.

Phenology parameters included in WTDB

Parameter	Description
PHENJUV[1..4]	Duration of juvenile growth stage, i.e. from emergence to flowering, given as the average [1] and variance [2] of the duration. The time scale can be days, day-degrees or photothermal time, in which daily day-degrees are multiplied by (day length minus base day length). As needed, the base temperature for day-degree calculation is given [3] together with base day length [4].
PHENFLO[1..4]	Duration of flowering stage, i.e. from beginning to end of flowering. Parameters [1..4] as above.
PHENMAT[1..4]	Duration of seed maturation, i.e. the period from a flower withers until its seeds have matured. Parameters [1..4] as above.

Competition parameters included in WTDB

Parameter	Description
COMPHYP[1..2]	Hyberbolic yield loss equation (Cousens 1985) given as the yield loss per plant at low weed density (Cousens' *i*) [1] and the maximum yield loss at high weed density (Cousens' *a*) [2].
COMPCON[1..6]	Conductance model of plant competition (reviewed by Benjamin 2007). A plot of $y=\ln$(leaf area) on $x=\ln$(shoot biomass) yields a slope [1] and intercept [2]. Another plot of $y=\ln$(crown zone area) on $x=\ln$(shoot biomass) yields

	another slope [3] and intercept [4]; 'crown zone area' means the area of the circle circumscribing the whole shoot as seen from above, i.e. a measure of how much the plant fills. Finally we need the light extinction coefficient *k* of de Beer's law [5] and the light use efficiency in g/MJ [6].
COMPHEIGHT	Maximum plant height at maturity in cm. This is likely to differ among agro-environments. Metadata should state the crop and soil conditions.
COMPRGR	Relative growth rate of shoot biomass per day or day-degree. This the growth rate in the early phase when growth is exponential.

Fecundity parameters included in WTDB

Parameter	Description
FECUNDITY[1.2]	Fecundity in relation to mature plant biomass. A plot of *y*=ln(seed production) on *x*=ln(shoot biomass) yields a slope [1] and intercept [2].

2.2.4. Data harvesting

The technical foundation of the database was implemented during summer 2007. Since then team members have filled in data on the weed species, which they volunteered to be in charge of. At the moment (M18) data for 14 species have been entered (see table further down).

2.2.5. Analysis

A first analysis of the data in WTDB will be presented by Jonathan Storkey (RRES) at the International Weed Science Conference in Vancouver, 23-27 July 2008.

2.2.6. Joint experiments

The collaborative work with estimating the parameters of WTDB led to the conclusion that some parameters (describing weed phenology, i.e. rate of development) were currently not well-described. A protocol for carrying out a joint experiment to estimate these parameters across Europe will be discussed at the next workshop in November 2008 at RRES to be carried out in 2009 and 2010 as funding permits.

2.2.7. International interest

The project has already attracted international interest, and the workshops have been attended by three extra-ENDURE scientists, coming from University of Iowa-Ames, University of Maine and University of Wisconsin. Their inputs at the workshops were highly valuable and had concrete effects on the decisions taken.

Following the third workshop, the participant Ed Luschei, University of Wisconsin, took initiative to raise funding to invite two project members, Marleen Riemens (PRI) and Niels Holst (AU), as invited speakers to a session at the Weed Science Society of America & Southern Weed Science Society Conference, Florida, 9-12 February 2009.

3. Conclusions

- We have successfully established a team reaching broadly across ENDURE and even outside. The team is dedicated to the task and is highly satisfied with the project practices and the progress made.
- The Weed Traits Database is now functional and is open for additional data entry as well as analysis.
- The Weed Traits Database has been instrumental in defining precisely the traits of most importance to weed dynamics, distribution and competitiveness and in pinpointing parameters, for which joint experimental work is necessary.
- The Weed Traits Database, together with the WeedML modelling language, holds promise of defining an international standard for trait-based analysis and modelling of weeds, as attested by the international interest this project has already attracted.
- Therefore we judge that the chances for attracting research funding to this project are high.

4. Perspectives

The perspectives for living up to the goals set for the Weed Traits Database, through the usage scenarios defined as part of the project requirements (usage 1 to 9, section 2.1.1), are good since we have already begun using the database as envisioned. Thus

- the first statistical analysis has been carried out and will be presented at an international conference (usage 1 and 8),
- experiments are currently being designed according to the gaps in knowledge highlighted by the database (usage 6),
- discussions on the database at the workshops have given the participants new insights into weed ecology (usage 7),
- and the international interest in our work is increasing (usage 9).

As the other track of the project matures, the development of the WeedML modelling language, the Weed Traits Database will increase in value as the new, WeedML-based models will be able to draw upon the information collected in the database.

This will be a truly innovative step forward in weed science, in fact, in the whole field of ecological modelling, as the Weed Traits Database and WeedML will facilitate truly joint, international research on weed ecology.

In the long run both these new research tools will improve our understanding of weed ecology and thus help us improving current weed management practices throughout Europe.

Table showing the number of records in the weed traits database (WTDB) for each trait and species (counted in M18).

Trait	ABUTH	ALOMY	AMBEL	APESV	BEAVX	ECHCG	PAPRH	POLAV	POLCO	POLPE	RAPRA	SINAR	SOLNI	STEME
COMPHEIGHT (MAX)	10	4		1		2	1				1	3	4	1
COMPHYP (COUSSENS_I)	22	1	3	7		2				1	6	4		3
COMPHYP (COUSSENS_A)	22	1	10	7		4				1	6	4		3
COMPRGR (-)	7	5		1									1	3
FECUNDITY (SLOPE)	1	1		1						1			2	4
FECUNDITY (ICEPT)	1	1		1		2				1			2	
GERMBASE (-)	1	1	1		1	3		1		1	2	1	3	1
GERMCAL (PCTJAN)	2	3		4	4	1	1	3		5	2	5		1
GERMCAL (PCTFEB)	2	3		4	4	1	1	3		5	15	5		1
GERMCAL (PCTMAR)	2	3		4	4	1	1	3		5	5	5		1
GERMCAL (PCTAPR)	2	3		4	4	1	1	3		5	19	5		1
GERMCAL (PCTMAY)	2	3		4	4	1	1	3		5	17	5		1
GERMCAL (PCTJUN)	2	3		4	4	1	1	3		5	7	5		1
GERMCAL (PCTJUL)	2	3		4	4	1	1	3		5	7	5		1
GERMCAL (PCTAUG)	2	3		4	4	1	1	3		5	5	5		1
GERMCAL (PCTSEP)	2	3		4	4	1	1	3		5	7	5		1
GERMCAL (PCTOCT)	2	3		4	4	1	1	3		5	3	5		1
GERMCAL (PCTNOV)	2	3		4	4	1	1	3		5	8	5		1
GERMCAL (PCTDEC)	2	3		4	4	1	1	3		5	17	5		1
GERMCHILL (CHIREQ)		1		2	1	4	1	1	1	1		2		
GERMDEPTH (BEST)	1	3	1	2	1			1	1	1	2	1	1	5
GERMDEPTH (DEEPEST)	1	2		2	1			1	1	1			2	4
GERMLIGHT (-)	1	1	1	2	1	3				1	1	3	1	6
GERMTOT (DISTURBED)	3	1		1	2	4	2	1		1	4	1		3

GERMTOT (UNDISTURBED)	6	1		1		2		1						1
PHENFLO (AVGDUR)			2	1	4	13	1				3	4		
PHENFLO (TEMPBASE)				1							1			
PHENJUV (AVGDUR)	3	2		1	1			2		1	2	4	1	1
PHENJUV (VARDUR)	1	2			1			2			1			
PHENJUV (TEMPBASE)		2		1	2						1	2		1
PHENJUV (PHOTBASE)														1
PHENMAT (AVGDUR)	2		2	1	1	1	1					4		1
PHENMAT (VARDUR)														1
PHENMAT (TEMPBASE)			1	1	1									
PHENMAT (PHOTBASE)											1			
SEEDCOAT (-)	1				1						2	2		1
SEEDMASS (-)	4	4	3	1	1	2	2	3	2	4	3	4	6	9
SEEDPER (UNDISTURBED)	2	5			1			2		1				2
SEEDPER (DISTURBED)	1	6		1	2	1	2				2	1	1	2