Future management of arable perennials - an introduction to the project AC/DC-weeds

Zukünftiges Management perennierender Unkräuter – eine Einführung in das Projekt AC/DC-weeds

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Abstract

Creeping perennial weeds have strong negative impacts on arable production. The common control practices are intensive inversion tillage and chemical herbicides. However, these traditional methods negatively affect non-target species and the environment.

The objective of the SusCrop-ERA-NET funded European project 'AC/DC-weeds' is to implement agro-ecological management for creeping perennials in arable farming. The overall aim of this project is to reduce plough-tillage in organic and conventional farming, and to replace glyphosate in the latter system. From 2019 to 2022, this project involves seven partners from five European countries. Focusing on three important perennial species in central and northern Europe (*Sonchus arvensis*, *Cirsium arvense* and *Elymus repens*), AC/DC-weeds will thoroughly study the ecology and agronomical management of these species through systematic literature reviews and experiments. Novel agro-ecological management of these species is examined in field experiments and semi-field approaches. Innovative technology will be used to identify and monitor the distribution of these weeds on fields. Qualitative models are developed to make use of existing knowledge and expertise of the influences on perennial infestations in management decisions. A graphic web tool will enable visualization of the growth of the species and the effects of weed management. Environmental and economic evaluations on different weed management accompany the experimental and modelling work.

Keywords: Agro-ecological management, *Cirsium arvense,* competition, creeping perennial weeds, disturbance, *Elymus repens, Sonchus arvensis*

Zusammenfassung

Mehrjährige Wurzelunkräuter beeinträchtigen die ackerbauliche Produktion. Verbreitete Bekämpfungspraktiken sind intensive wendende Bodenbearbeitung und chemisch-synthetische Herbizide. Diese gebräuchlichen Methoden haben allerdings unerwünschte Effekte auf Nicht-Ziel-Organismen und die Umwelt.

Ziel des SusCrop-ERA-NET geförderten Europäischen Projekts 'AC/DC-weeds' ist es, agrarökologisch basiertes Management von mehrjährigen Wurzelunkräutern zu etablieren. Beiträge zur Reduktion von wendender Bodenbearbeitung in ökologischen und konventionellen Ackerbau und dem Ersatz von Glyphosat in letzterem zu liefern, sind die übergeordneten Aufgaben. Getragen von sieben Partnern aus fünf europäischen Ländern läuft das Projekt von 2019 bis 2022. Drei wichtige mehrjährige Arten in Nord- und Zentral-Europa werden fokussiert (*Sonchus arvensis, Cirsium arvense* und *Elymus repens*). Zu diesen Arten erfasst AC/DC-weeds Ökologie und Wirkungen des agronomischen Managements mit Experimenten und einer systematischen Literatur-Recherche. Neues agrar-ökologisches Managements der Arten wird in Feldversuchen und Semi-Feld Versuchen untersucht. Für die Erfassung werden innovative Technologien eingesetzt, um der nesterweisen Verteilung im Feld gerecht zu werden. Qualitative Modelle nutzen Wissen zu den Einflussfaktoren auf das Vorkommen von mehrjährigen Unkräutern, um sie für Entscheidungen nutzbar zu machen. Das Wachstum der Arten und die Effekte des Managements werden einfach und grafisch in einer Web-Anwendung visualisiert. Die Versuche und Modellierungen werden begleitet durch eine Umweltbewertung- und ökonomische Kalkulationen.

Stichwörter: Agrar-ökologisches Management, ausdauernde Unkräuter, *Cirsium arvense, Elymus repens*, Konkurrenz, *Sonchus arvensis*, Störung

Introduction

Creeping perennial weeds have strong impacts on arable production, causing crop quantity and quality losses unless controlled. In the short term, these losses are obvious in the main crop, when weed plants compete for resources with the crop plants. Moreover, weeds develop surviving strategies which influence the long-term success in cropping systems including the sequence of all main crops and the period between.

In central and northern Europe, *Sonchus arvensis* (perennial sowthistle), *Cirsium arvense* (creeping thistle) and *Elymus repens* (couchgrass) are the three major perennial weeds occurred in arable lands. Creeping perennials ensure their lifeform by subterranean storage organs, like roots or rhizomes. Their subterranean clonal systems facilitate survival and spatial spread in arable fields by vegetative sprouting. Classified as geophytes which regenerate their above ground plant biomass from subterranean sources, they can in general occur in different agroecosystems like grazed pastures, arable fields cropped with annual crops and perennial crops (e.g., orchards). Some creeping perennial species are strongly adapted to arable land where frequent disturbance occurs and competitive conditions vary depending on crops and their sequence.

The common practices of arable farmers to control these creeping perennial weeds are intensive inversion tillage and herbicides (especially glyphosate; SOANE et al., 2012; SALONEN et al., 2013; ANDERT et al., 2018). However, intensive inversion tillage by ploughing not only consumes lots of energy (TULLBERG et al., 2007), but also diminishes the soil biological activities (PIMENTEL et al., 1995; LEYS et al., 2007; KNAPEN et al., 2008). Indiscriminate use of herbicides has side effects on human health, non-target species, and the wider environment (e.g., water quality) (NIEMANN et al., 2015). Agro-ecological management claims that sustainable agricultural systems should rely as much as possible on ecological processes to ensure long-term food security, human health and environmental protection (DURU et al., 2015). Indeed, integrated weed management for perennial weeds demands to explore, compare and evaluate such novel strategies.

The AC/DC-weeds Project

The objective of AC/DC-weeds is to implement more and better agro-ecological management for creeping perennials in arable farming. The overall aim of this project is to reduce plough-tillage in organic and conventional farming, and to replace glyphosate in the latter system.

Funded by SusCrop ERA-NET, AC/DC-weeds is a multi-national project involving seven partners from five EU member states. Started on 1st April 2019, the duration of this project is three years. Its partners include University of Rostock (Germany), Norwegian University of Life Sciences and Norwegian Institute of Bioeconomy Research (Norway), Natural Resources Institute Finland (Finland), University of Copenhagen (Denmark), INRA - AGroecologies, Innovations & Ruralities and INRA Environment and Agronomy (France).

This project includes seven work packages (WP), with the key structure and methodology summarised in Figure 1.

The main emphasis of AC/DC-weeds is to expand ecological data and knowledge for three perennial species (*Sonchus arvensis, Cirsium arvense* and *Elymus repens*) by investigating how disturbance and competition suppress the reproductive capacity of creeping organs and the spread of the species (Fig. 1, WP Species).

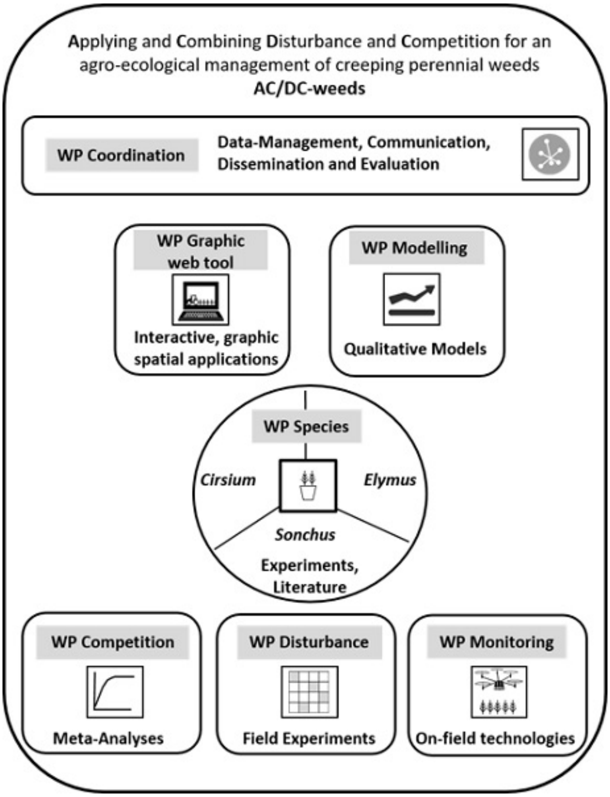

Fig. 1 AC/DC-weeds in a nutshell.

***Abb. 1** AC/DC-weeds auf einen Blick.*

Sonchus arvensis is native to Europe and Asia (LEMNA and MESSERSMITH, 1990). As weed it is especially problematic in Northern Europe in arable crops. The species reproduces vegetatively by creeping thickened roots and by an abundant seed production (LEMNA and MESSERSMITH, 1990). The creeping roots are located from 5-12 cm in soil and produce aerial shoots and long vertical roots from adventitious buds. Clonal spread may vary from 0.5 to 2.8 m per year and seeds may be spread by wind for up to 10 m distance (LEMNA and MESSERSMITH, 1990). The growth of roots fragments planted in autumn the previous year or in spring may give 1.5-2.2 m to 10-15 m long thickened roots (TØRRESEN et al., 2010). The creeping roots survive during winter to the next spring. *S. arvensis* is sensitive to light and to crop competition (VANHALA et al., 2006). There are few studies on the effect of competition on *S. arvensis*.

Cirsium arvense, native to Europe, today occurs in arable and grasslands in temperate zones all over the world. *C. arvense* has an expanded root system which can reach 3 m deep into the soil (TILEY, 2010). The plant expands in patches with adventitious roots. Nevertheless, sexual reproduction is important for the dioecious species, resulting in high genetic diversity even in patches (HETTWER and GEROWITT, 2004; BOMMARCO et al., 2010). *C. arvense* is very sensitive to light competition (DAU, 2012). Ploughing disturbs the plant only superficially but the effect is highly related to timing and depth (BRANDSÆTER et al., 2011; 2017). Like for other perennials it is a fundamental requirement to understand the species reaction to disturbance and competition both below and above ground - for *C. arvense* this is additionally complicated due to the dioecious reproduction.

Elymus repens is widespread throughout the world. It propagates through both seeds and underground rhizomes, which function as overwintering organs. Vegetative cloning is more important than sexual reproduction in maintaining its population (WERNER and RIOUX, 1977). The majority of undisturbed rhizome networks tend to be located in the top 10 cm of the soil, easily reachable with tillage equipment. The highest potential for rhizome production is in summer, though even at relatively high latitudes growth can continue throughout the autumn (BOSTRÖM et al., 2013). *E. repens* displays a high morphological variation and the efficacy of different control methods shows a strong temporal and spatial variation: e.g. soil cultivation (RINGSELLE et al., 2016), rhizome fragmentation and/or mowing (BRANDSÆTER et al., 2012; LÖTJÖNEN and SALONEN, 2016; BERGKVIST et al., 2017). Under favourable growing conditions rhizome fragmentation in a growing crop can significantly reduce *E. repens'* rhizome production (BERGKVIST et al., 2017; RINGSELLE et al., 2018), however, it does not necessarily reduce the growth of this weed (KOLBERG et al., 2018).

All sources of literature on biology and control measures of the three species are collected and results systemized. Small-scale experiments with three weed species will implement factors disturbance of the above/below-ground parts and competition, either separately or in combination at different growth stages of weeds. Based on literature and experiments, species-specific ecological rules will be outlined on growth strategies, storage and spread (space, time, and soil depth) affected by disturbance and competition.

Continuous and strong competition is one strategy to suppress perennials. In periods between main crops, light competition can be enhanced by cover crops. In the WP Competition (Fig. 1) we collect reports on perennial weeds from experiments with cover crops and perform a meta-analysis to identify conditions for suppression. Traits of cover and companion crops describing and explaining the performance will be selected.

Disturbance is another strategy to manage perennials. We investigated disturbance in field experiments (WP Disturbance, Fig. 1). Two ways of disturbing the plants are tested: root cutting and defoliation. For root cutting a prototype provided by a committed partner is tested. Bio-based herbicides are applied to test their effect of defoliation. As treatments with cover crops are included in the experiments, an ambitious goal is to test whether disturbance and competition can be combined.

Perennial weeds grow in patches, which complicate weed control experiments, population studies and the estimation of their competitive abilities. The patchy distribution of perennial weeds calls for site-specific weed management, which requires cost-effective weed monitoring. We investigate to monitor perennial field infestations with unmanned aerial vehicle (UAV) imagery because UAV data collection is cost-effective and new weed detection methods based on aerial images show promising potentials. Success criteria will be detection accuracy, capacity, cost-effectiveness and ease of use. To benefit from the fast-developing research of image analysis (e.g. convolutional neural networks), annotated images will be shared to make validation and benchmarking possible for computer scientists.

The work on experiments, meta-analyses and detection algorithms mentioned above will widen our knowledge on agro-ecological processes determining the species success in arable farming. Besides, two products will pave the way for practical implementations: a qualitative decision model (WP Modelling, Fig. 1) and a web-visualisation of the growth of the perennial species above and below ground (WP Graphical Web Tool, Fig. 1).

The general aim of WP Modelling is to provide models to integrate agro-ecological management decisions for perennials weeds. Perennials resist the way of population modelling because of their clonal lifestyle with subterranean connections and storage. Modelling populations of these species must rely on new approaches, which includes spatial information and the subterranean part of the infestations. However, there is very few quantitative data, especially of the below ground part. Qualitative modelling can be used to overcome the shortage in full quantitative data when expertise, knowledge and weak data are available. For this purpose, AC/DC-weeds partners join data and expertise. An innovative modelling framework named IPSIM (Injury Profile SIMulator) will be used (AUBERTOT and ROBIN, 2013). This qualitative modelling platform provides a tool to design aggregative qualitative network models to predict the impact of cropping practices, soil, weather and field environment on infestations of perennials. A dataset representing a range of weather patterns, soils and cropping practices will be compiled to assess the predictive quality of the models in comparing simulated and observed values. We aim to develop three models (one for each weed species of interest).

Regarding the patch building of creeping perennial and the definite need for a long-term agro-ecological management, innovative method of visualizing field infestations will be used (WP Graphic web tool, Fig. 1). Easily accessible, specific information underpinned with understandable illustrations will improve interest Understanding the effects of applying and combining disturbance and competition on perennial is crucial for agro-ecological management. Therefore, the tool will allow farmers and advisors to explore how managements affect perennial infestations and thus, to understand the consequences of different applications of disturbance and competition on field infestations.

Besides being effective against perennials, agro-ecological management should be more sustainable compared to the common practice. Environmental and economic effects of the perennial weed management will be investigated for both common practices and alternative methods investigated in this project. An environmental impact assessment (EIA) is adapted and applied. This approach takes into account all relevant impacts, including energy use. The energy use efficiency will also be compared between management approaches. Cost-effectiveness analyses will be conducted to estimate the relative effectiveness of different perennial weed managements (e.g., in terms of € / reduced weed patches, reduced sprout densities). We also hypothesize that perennial infestations on arable land has an influence on land value, renting contracts and social perception of farm management effects. This hypothesis will be tested in an interview-based survey on farms.

Current Progress

Field experiments on disturbance (root cutters, tillage, and mowing) and competition (cover crops and light) of the three focused perennial weeds have been established. The partners also regularly take drone pictures of weed field patches to assist the analyses. Lab and small scale experiments of temperature and herbicide effects on weed seedlings and root fragments are outlined. To assist efficient knowledge/literature sharing among partners, we have designed the structure of an article bank that includes key indicators useful for each WPs. Partners are continuously adding data to the article bank. AC/DC-weeds partners are planning to present results in the German Conference on Weed Biology and Weed Control in 2022.

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