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Rothamsted Research Annual Report 2002-2003

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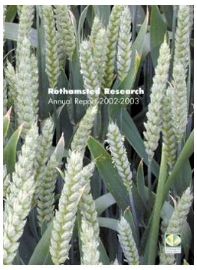

Weed Population Dynamics

Rothamsted Research

Rothamsted Research (2003) *Weed Population Dynamics ;* Rothamsted Research Annual Report 2002-2003, pp 24 - 27

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Research into weed population dynamics contribute to our understanding of weed behaviour. Studies of the responses of weeds to environmental stochasticity and of the physiological basis for differences in such responses between weed species are forming the basis for predictive, computer-based, systems of weed management. Such systems are taking into account the dual role of weeds in the arable environment as competitors with the crop and valuable contributors to biodiversity and food webs.

ROTHAMSTED RESEARCH

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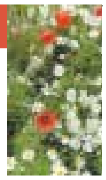

Weed population dynamics and its role in developing ecologically sustainable management systems

Peter J W Lutman, Laurence R Benjamin, John W Cussans, Jonathan Storkey

Typical annual weeds of winter cereals (*Papaver rhoeas*, *Tripleurospermum inodorum*. (left)

Yield losses from weeds on the "classical" Broadbalk winter wheat experiment (Figure 1) show that as the time from a fallow year (when no crop is grown and full weed control is possible) increases, crop yield loss also increases, as a result of the population expansion of weeds. These data also reveal the level of variability that occurs in these natural processes. Crop yield loss varies from 0% to nearly 40% in the years immediately following fallow when weed population levels are at their lowest. These data illustrate two important principles. Firstly, that an understanding of the population dynamics of weeds is central to any attempt to understand and predict their behaviour and, secondly, that the variability that can occur in weed behaviour must be incorporated into the predictive process.

Population dynamics

Research into the population dynamics of noxious arable weeds such as black-grass (*Alopecurus myosuroides*), wild-oat (*Avena fatua*) and cleavers (*Galium aparine*) was in vogue ten years or more ago. Stephen Moss at Rothamsted devised a model for *A. myosuroides* that created the basic framework from which to explore the effects of changed management on populations (Figure 2). The emphasis has now changed, as developments in computer-based decision support systems have provided an opportunity to exploit these studies far more effectively in the promotion of economically sound weed control decisions. These tools were initially designed to explore methods of effective weed control, but they now have a role in designing environmentally targeted weed management systems, aimed at

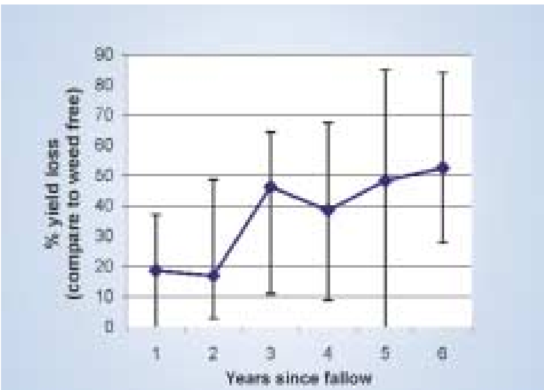

Figure 1. The impact of the number of years since a fallow on winter wheat yield loss due to weeds on the Broadbalk experiment (vertical bars show the range of responses)

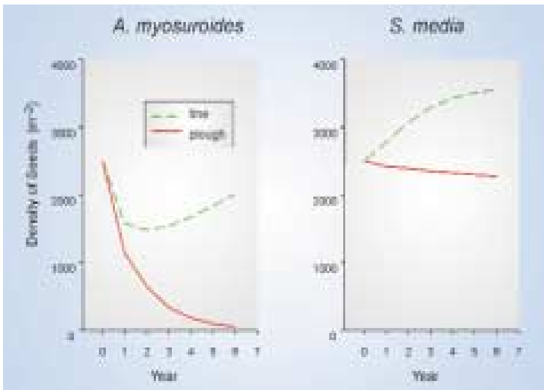

Figure 2. Prediction of the effect of ploughing and tine cultivation every year of a 6-year rotation on the density of seeds in the soil and in the seedbank for *A. myosuroides* and *S. media* assuming 95% kill of plants by the herbicides

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Weed species	No. of associated insect species	Importance in bird diets	Competitive indices +
Avena fatua	<10		5.0
Alopecurus myosuroides	<10		12.5
Galium aparine	30		1.7
Sinapis arvensis	38	**	12.5
Tripleurospermum inodorum	30		12.5
Stellaria media	70	***	25
Poa annua	52	**	50
Senecio vulgaris	47	**	83
Cerastium fontanum	22	**	(25)
Veronica persica	<10		62.5
Viola arvensis	<10	**	200
Chenopodium album	30	***	(25)
Polygonum aviculare	60	***	50
Sonchus arvensis	28	*	(50)
Rumex obtusifolius	78	**	?

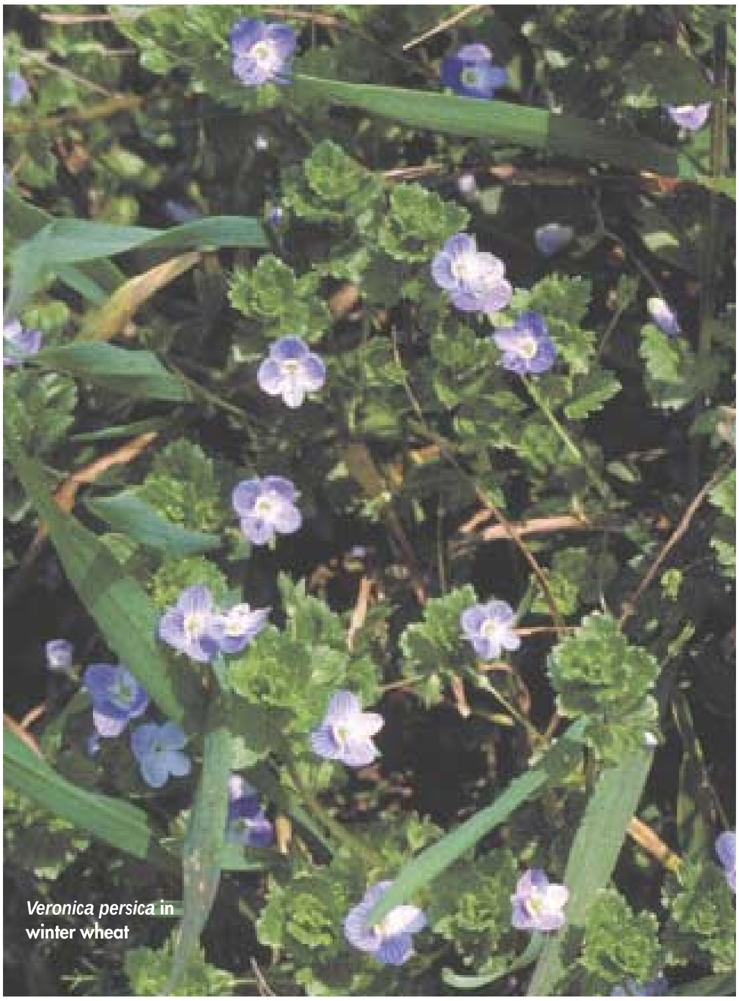
+ number of weed seedlings to cause a 5% yield loss
Figures in brackets – expert opinion/extrapolated values

Table 1. The competitive impact of a range of common weeds and their importance for invertebrates and birds

preserving rarer and beneficial indigenous plants of arable ecosystems. A further technological advance has been the development of spatially selective weed control that uses satellite-based global positioning systems (GPS). This enables herbicides to be applied to geo-referenced mapped areas of the field. In such systems, patches of weeds can be treated, leaving other areas of the field untreated. Decisions on which areas to treat can be based both on the impact of particular weeds on the crop and their population dynamics.

Weeds provide food for invertebrates and birds and are thus important contributors to functionally valuable biodiversity in arable ecosystems (Table 1). There have been declines in arable weeds and farmland bird species over the last 50 years, apparently associated with the intensification of agriculture. The causes of these declines are complex but there is a suggestion that maintenance of a diverse population of weed species is beneficial for arable field ecosystems. This ecological role conflicts with the traditional perception of weeds only as plants detrimental to yield. Consequently, there is a need to balance the control of aggressive competitive species and the retention of less damaging species that offer environmental benefits. This dual view of weeds poses a challenge for their management and emphasises the need for a sound understanding of population dynamics.

Recent research has enabled us to improve our knowledge and models of weed population dynamics allowing more precise prediction of population change and a better understanding of the degree and causes of variability. Some of this work is of direct application while other components are exploring more fundamental aspects such as matrix modelling techniques and the physiological basis for the different behaviour of weed species. It is not possible to study every one of the 200 or so plant species that can be classified as weeds, but it may be possible to group species into a restricted number of classes that define their phenology, growth and impact on the crop and the environment. Weed species deploy a limited number of strategies enabling them to thrive in the specialised environment of an arable field. Some of these strategies will be



Veronica persica in winter wheat

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Figure 3. Actual and modelled response of *G. aparine* (measured as plant biomass) in winter wheat under high or low moisture conditions

antagonistic to the crop and seriously reduce yield. However, it is possible that a class of weed species can be identified which has a growth and reproduction strategy that is complementary to the requirements of the crop both spatially and temporally. Improved predictions of weed impact will help us to quantify the effects of changes in cultural practices on species that need to be effectively controlled, as well as those that offer environmental benefits and need to be retained.

Dealing with variability

One area of our work has focussed on identifying key environmental variables that cause variability in plant growth and fecundity in arable habitats. This work has made use of mechanistic simulation models of plant growth in mixtures together with an extensive array of basic physiological parameters.

The work has quantified the impact of environmental stochasticity on the growth and reproduction of some key weed species within a single year. Having quantified the likelihood of different levels of fecundity for weeds, the information can be incorporated into a stochastic version of our weed population dynamics model.

Soil moisture is a key cause of variability in weed species like *G. aparine* (cleavers) and our work has revealed the rooting and water-use characteristics of this species, enabling us to predict the impact of variable soil moisture. The success of a mechanistic simulation model at describing the contrasting growth of a population of cleavers under rainfed compared to irrigated conditions is shown in Figure 3.

Weed management decisions – the role of population dynamics

The apparently conflicting dual role of weeds in arable fields makes decision making on weed management increasingly difficult. The development of a Decision Support System (DSS) for weed management in winter wheat (WMSS) in collaboration with ADAS, SRI and SAC, provides a mechanism to deliver solutions for the complex issues surrounding weed management. Such a system takes into consideration the impact of weeds on crop yield and offers optimum economic solutions. It also highlights the ecological value of the species and estimates the consequences of control techniques for both current and future crops, based on estimates of seed production and losses.

The real size of the threat from weeds lies in the large number of weed seeds in the soil that can germinate and infest current and future crops. Within the DSS, the numbers of weed seeds in the soil and the numbers of mature weed plants that grow to compete with the crop are calculated through the course of a six-year crop rotation. The rotation must include winter wheat in one of the first two years but can include other crops such as oilseed rape, potatoes and spring barley in other years.

The simulation is carried out iteratively by calculating how many seeds there will be in the soil at the start of the next production year, given the numbers in the soil at the start of the current production year. These calculations are based on the numbers of:

seeds that move from shallow to deep layers with cultivations;
seeds that produce seedlings;
seedlings killed by herbicides or hoeing;
plants that produce new seeds;
new seeds that are viable;
new seeds that are eaten by predators;
seeds that survive in the soil from one year to the next.

Given a specified sequence of crops, the DSS can calculate the most cost-effective combinations of weed control measures to ensure that the population of a particular weed is not allowed to increase to uncontrollable levels. Similarly, the husbandry that minimises the risk of extinction for rare or beneficial species can be identified.

This research is providing fresh insights into old problems and increasing our understanding of the role that weeds play in determining biodiversity in the farmland ecosystem. The programme ranges from fundamental studies of the role of weeds as crop competitors in a highly variable environment, and providers of food for invertebrates and birds, to developing systems to translate this information for the use of growers and advisors.