THE PREDICTION OF COUCH INFESTATIONS - A MODELLING APPROACH

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Summary Some demographic data for populations of Agropyron repens (L.) Beauv. are presented. A mathematical model for simulating population growth is described. The use of the model for predicting the size and growth of couch populations under various management regimes is demonstrated.

INTRODUCTION

The importance of couchgrass, Agropyron repens (L.) Beauv. as a weed of arable land is well known. A review by Hakansson (1975) considered it to be the major perennial weed problem in Northern Europe. The difficulty this species presents for weed control lies in its potentially vast reserves of dormant rhizome buds. Systemic herbicides such as glyphosate provide a very effective means of control but usually not total eradication. There is therefore a need to be able to predict growth rates of couch populations in various environments so that the effect of control measures may be evaluated.

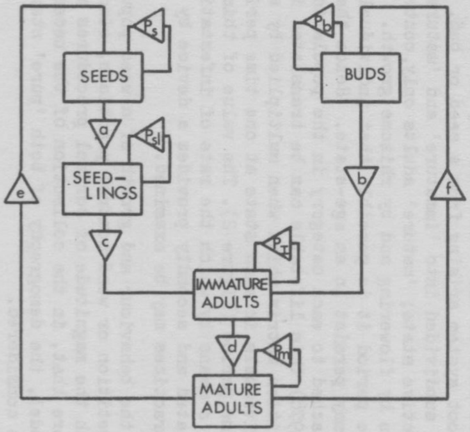
We have previously described a mathematical model for predicting the sizes of weed populations (Mortimer et al., 1978) and suggested its use as a means of evaluating weed control procedures. The model relies on the acquisition of detailed demographic data in the field for the particular weed species under study. Such data are very incomplete for Agropyron repens (Sagar and Mortimer, 1976) although there have been many studies on aspects of its biology and ecology (for example Courtney, 1977; Williams, 1973). This paper describes the development of the model for couch populations and some field studies performed on couch in order to obtain the relevant demographic data for its application.

THE MODEL

The construction of the model for Agropyron repens follows the approach taken in Mortimer et al., 1978. The diagrammatic life table presented in Figure 1 distinguishes five 'age-states' (Rabotnov, 1969) within the life cycle and illustrates the fluxes or transitions in unit time that may occur. An adult plant is defined as a tillering shoot system arising from a seed or bud. The adult aerial plant fraction is subdivided into 'immature' and 'mature' categories on the basis of reproductive state; 'mature' adults only, contribute in this model to seed and bud banks by flowering and by rhizome growth. It is envisaged that within a single time period it is possible that individuals (seeds, buds, seedlings or adults) may persist in an age-state. Hence there is a probability of this occurrence attached to each category in the population. As described by Mortimer et al. (1978) this lifetable can be translated into a matrix model consisting of a transition matrix which when multiplied by a column vector of the number of individuals in each state at one time period, gives the numbers present at the next time period (Figure 2). The value of this approach is that it allows firstly a means by which the rate of infestation or population growth may be calculated and secondly provides a device by which the effects of differing control practices may be examined.

It is important to understand the behaviour and growth of a weed population unrestricted by interspecific competition or weed control practices, since this provides the template against which the magnitude of control procedures may be measured. It is essential therefore that, in the collection of the necessary data for the application of the model, the demography of both 'pure' stands of couch as well as 'managed' ones be considered.

Fig. 1. Diagrammatic life table for *Agropyron repens*.



Demographic events taking place in any one time period:

Proportions
- P_s - SEEDS SURVIVING.
- P_{sl} - SEEDLINGS SURVIVING.
- P_I - IMMATURE ADULTS SURVIVING.
- P_m - MATURE ADULTS SURVIVING.
- P_B - BUDS SURVIVING.
- a - SEEDS GERMINATING.
- b - BUDS GERMINATING.
- c - SEEDLINGS SURVIVING TO BECOME IMMATURE ADULTS.
- d - IMMATURE ADULTS SURVIVING TO BECOME MATURE ADULTS.

Fecundities
- e - NUMBER OF SEEDS PRODUCED BY MATURE ADULTS.
- f - NUMBER OF BUDS PRODUCED BY MATURE ADULTS.

Fig. 2. A matrix model of the life table of *Agropyron repens*

TRANSITION MATRIX ... COLUMN VECTORS OF AGE STATES

$$\begin{bmatrix} P_s & 0 & 0 & e & 0 \\ a & P_{SL} & 0 & 0 & 0 \\ 0 & c & P_I & 0 & b \\ 0 & 0 & d & P_m & 0 \\ 0 & 0 & 0 & f & P_b \end{bmatrix} \times \begin{bmatrix} S_t \\ SL_t \\ I_t \\ M_t \\ B_t \end{bmatrix} = \begin{bmatrix} S_{t+1} \\ SL_{t+1} \\ I_{t+1} \\ M_{t+1} \\ B_{t+1} \end{bmatrix}$$

S_t and S_{t+1} - the number of seeds at times t and t+1 respectively

SL_t " SL_{t+1} - " " " seedlings at times t and t+1 respectively

I_t " I_{t+1} - " " " immature adults at times t and t+1 respectively

M_t " M_{t+1} - " " " mature adults at times t and t+1 respectively

B_t " B_{t+1} - " " " buds at times t and t+1 respectively

METHODS

The long term monitoring of pure stands of couch was carried out on four colonizing populations established at the University Botanic Gardens, Ness, in October 1977. The central 1 m^2 area of pairs of plots (2m.x2m.) were either planted with 50 single node rhizome fragments (subsequently referred to as "rhizome plots") or with 500 seeds ("seed plots"). The above ground unit of the population chosen for study was the aerial shoot system. Monitoring of births and deaths of aerial shoots together with tiller and seed counts was performed at regular intervals (usually every two weeks) over a period of 34 months. Recognition of individual shoots in the first year was by mapping and subsequently by numbered plastic tags placed around the shoot. Seedlings were recognised by adjacent placement of coloured mapping pins. The bud fecundities of adult plants were measured by excavation of the plots at the termination of the experiment.

Monitoring of populations started from seed and single node rhizome fragment was performed similarly in field plots sown with winter wheat (var. Maris Huntsman) in October 1978. The survivorship of buried seed populations was examined over one year by following the monthly changes in viability of seed buried in nylon mesh bags at a range of depths from 0-10cm. The mortality of dormant buds on rhizomes was measured by monthly viability tests on bud populations of known age.

RESULTS AND DISCUSSION

Figure 3 shows the pattern of births of aerial shoots on a monthly basis in the pure stands established from rhizomes and seeds. Data are presented for the internal, initially colonised, $1m^2$ area of the plot and the external area latterly colonised 0.5m belt. Apart from the initial germination in the seed plots, seedlings are not included as there were very few and none progressed beyond the seedling stage. In all plots a similar temporal birth pattern was observed, namely peaks in the spring and autumn each year with troughs in mid-summer at the time of flowering (June-July) and in mid-winter. Numbers of births were generally higher in the rhizome plots than in the seed plots and colonization of the external area was earlier in the rhizome plots. This indicates a lag in the seed plots due to these effectively starting later and from an earlier age state (seedlings in April 1978) compared with the rhizome plots ('immatures' in December 1977). This is confirmed by the observation that flowering did not occur in the seed plots until 1979 whereas in the rhizome plots flowering occurred in 1978.

The pattern of mortality of adult shoots (Fig.4) clearly demonstrates that death was slight in the early phase of colonisation but increased with time, this being presumably an effect of increasing density.

Figure 5 shows the cumulative births and deaths/m^2 for all plots. This shows clearly the colonizing situation with births far exceeding deaths. There is tentative evidence in the third year (1980), in the seed plots, that regulation may be occurring to stabilize the size of the population. The absence of seedlings establishing to become adults within the plots suggests that whereas seed may be an important source for colonization of bare areas (as in the start of the seed plots), within an established stand, their role is not as important. The absence of any noticeable mortality in the external areas of the seed plots suggests that little significant regulation may be occurring and that the birth of additional adults will continue to occur in autumn 1980 in these areas.

Figure 6 illustrates the decline in the size of the viable buried seed population over one year. The results are subject to field variation but two conspicuous features emerged. The decrease in numbers from February through to April is due to germination and hence removal from the seed bank. After twelve months about 10% of the sown seed crop was near the soil surface. Slightly higher values were found at greater depths, probably due to enforcement of seed

Fig. 3. The pattern of births of aerial shoot systems of Agropyron repens. (——) internal area, (- - -) external area; R - rhizome plots, S - seed plots.

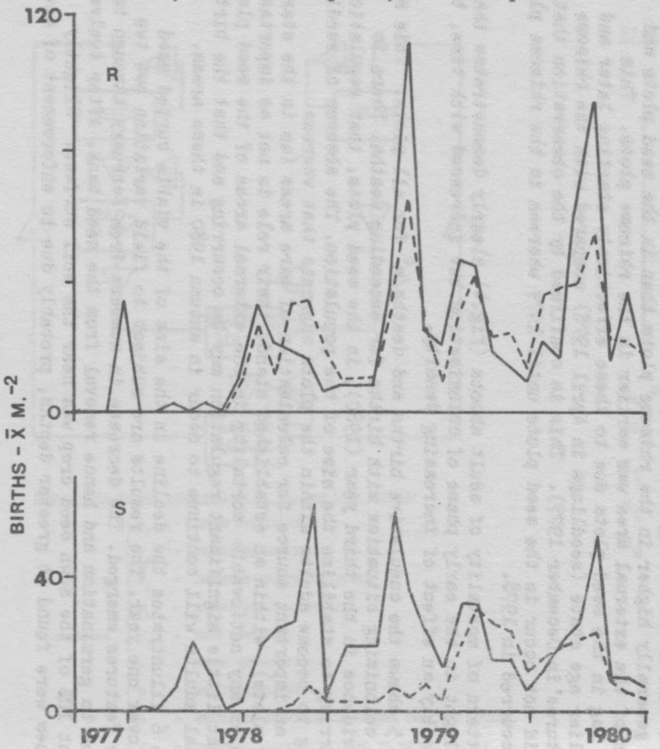


Fig. 4. The pattern of mortality of aerial shoot systems of Agropyron repens. Symbols as Fig. 3.

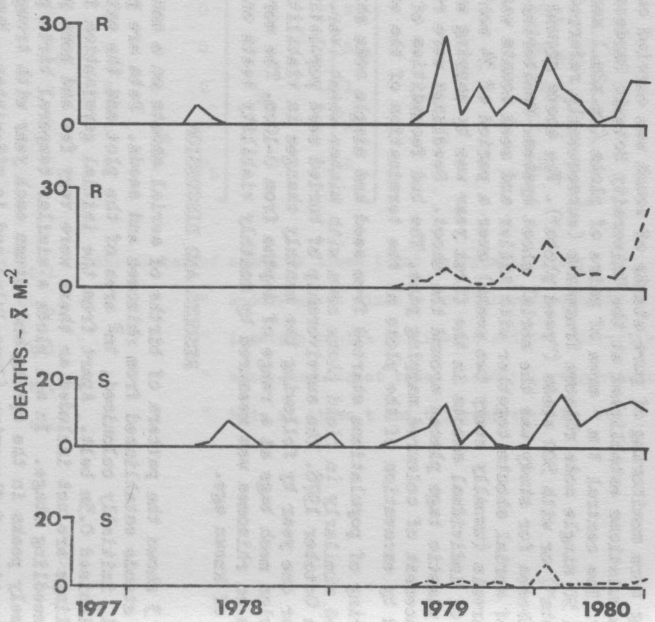


Fig. 5. Cumulative births and deaths in an aerial shoot population of Agropyron repens. Symbols as Fig. 3. Lines marked A are actual population sizes.

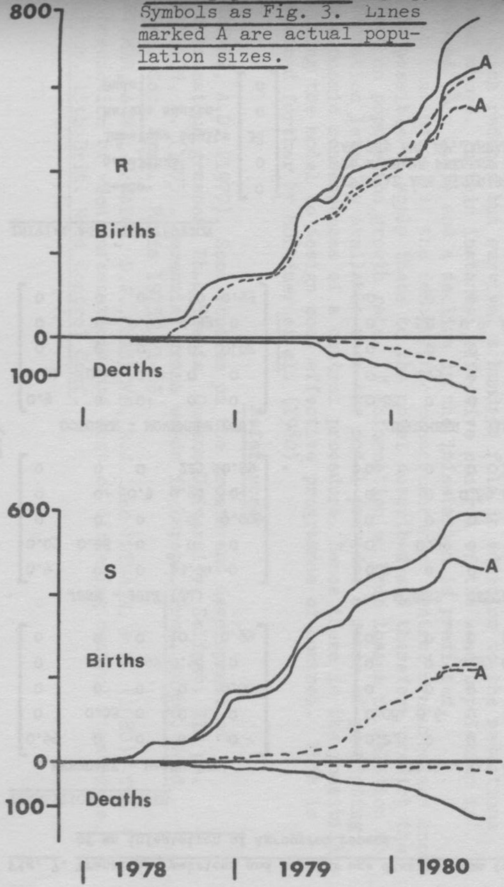


Fig. 6. Changes in the size of the buried seed bank of Agropyron repens.

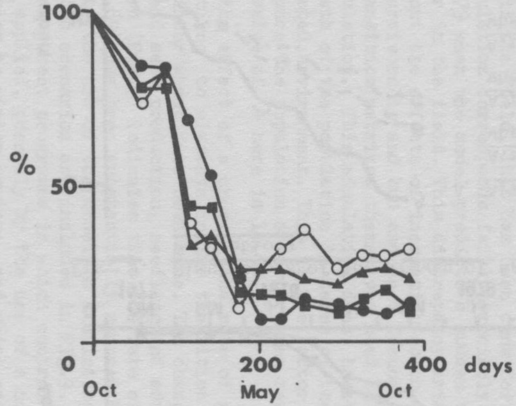


Fig. 7. Transition matrices and initial age distribution for the simulation of an infestation of Agropyron repens.

TRANSITION MATRICES

FEBRUARY - MARCH (FM)

$$\begin{bmatrix} 0.59 & 0 & 0 & 0 & 0 \\ 0 & 0.33 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.004 \\ 0 & 0 & 0.97 & 0.98 & 0 \\ 0 & 0 & 0 & 10 & 0.99 \end{bmatrix}$$

APRIL - MAY (AM)

$$\begin{bmatrix} 0.2 & 0 & 0 & 0 & 0 \\ 0.08 & 0.6 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.015 \\ 0 & 0 & 0.97 & 0.99 & 0 \\ 0 & 0 & 0 & 75 & 0.99 \end{bmatrix}$$

JUNE - JULY (JJ)

$$\begin{bmatrix} 0.9 & 0 & 0 & 13.74 & 0 \\ 0.05 & 0.66 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.004 \\ 0 & 0 & 0.9 & 0.98 & 0 \\ 0 & 0 & 0 & 225 & 0.99 \end{bmatrix}$$

AUGUST - SEPTEMBER (AS)

$$\begin{bmatrix} 0.9 & 0 & 0 & 0 & 0 \\ 0 & 0.59 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.004 \\ 0 & 0 & 0.89 & 0.99 & 0 \\ 0 & 0 & 0 & 100 & 0.99 \end{bmatrix}$$

OCTOBER - NOVEMBER (ON)

$$\begin{bmatrix} 0.9 & 0 & 0 & 0 & 0 \\ 0.01 & 0.46 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.02 \\ 0 & 0 & 0.97 & 0.99 & 0 \\ 0 & 0 & 0 & 50 & 0.99 \end{bmatrix}$$

DECEMBER - JANUARY (DJ)

$$\begin{bmatrix} 0.85 & 0 & 0 & 0 & 0 \\ 0 & 0.5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.004 \\ 0 & 0 & 0.9 & 0.97 & 0 \\ 0 & 0 & 0 & 0 & 0.99 \end{bmatrix}$$

INITIAL AGE DISTRIBUTION

$$\begin{array}{l} \text{Seeds} \\ \text{Seedlings} \\ \text{Immature adults} \\ \text{Mature adults} \\ \text{Buds} \end{array} \begin{bmatrix} 0 \\ 0 \\ 38 \\ 0 \\ 0 \end{bmatrix}$$

INITIAL AGE DISTRIBUTION CORRESPONDS TO NUMBERS PRESENT IN FIELD PLOTS AT THE END OF JANUARY 1978.

Fig. 8. A comparison of simulation and field results.

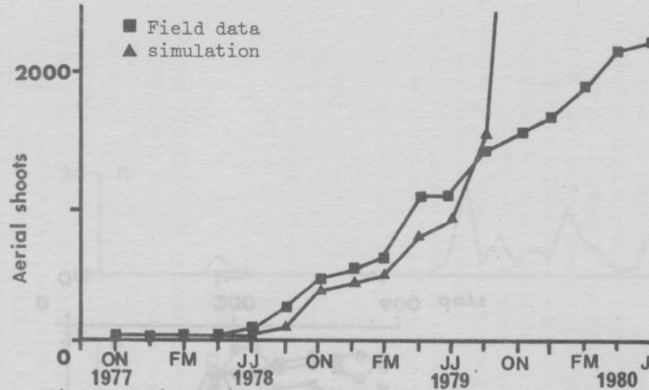
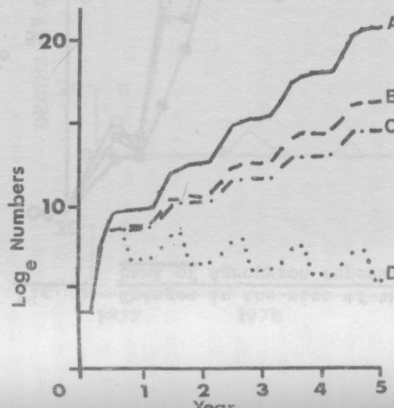


Fig. 9. Simulations of the growth of Agropyron repens populations.



A A.repens alone.

B A.repens in winter wheat.

C A.repens in winter wheat, Case A.

D A.repens in winter wheat, Case B.

See text for details.

dormancy. No significant change in viability of dormant buds was observed over a period of 20 months.

Use of the Model

With data from regular and frequent monitoring it is possible to choose the time interval over which the transition matrices will operate. We have chosen here a time period of two months and transition matrices for each two monthly period of the year have been constructed (Figure 7). The realism and precision of the model can be tested by comparing the results of a simulation with the data actually obtained in the field. This has been done for the rhizome plots in Figure 8. The simulation corresponds fairly precisely to events in the field until September 1979 when the model predicts a sudden vast increase in numbers which did not occur in the field. This discrepancy arises because the model does not take into account the effects of increasing couch density and consequent changes in adult survivorship and bud and seed fecundity. To improve realism, elements of the transition matrices themselves need to be made a function of the density of the population. This simulation does, however, allow the calculation of the rate of growth of the population in terms of the finite rate of increase (λ) in an unrestricted environment. This is the factor by which numbers change from year to year once the population structure has reached a stable age-state distribution. The value of λ here is 15.95.

To illustrate the effect of a crop on the rate of growth of a couch population, alterations to elements in the transition matrices based on data from the study in winter wheat have been made. The changes concern measured reductions in bud and seed production, seedling and adult survival. The resulting simulation (Fig.9) indicates that the rate of growth of the infestation (λ = 6.69) has been substantially reduced by the presence of the crop. To demonstrate the use of the model in simulating the effectiveness of control practices two scenarios are included in Fig.9. The first, Case A, envisages a weed management programme in which control of the couch population in winter wheat is applied, possibly by the use of a non-systemic herbicide, post harvest and prior to winter sowing; and which results in very low seedling survival, a ten fold reduction in the survival of mature adults, total mortality of immature adults and a halving of adult bud fecundity. The simulation predicts that whilst this programme lowers the rate of infestation (λ= 4.37) it clearly does not contain the infestation. In Case B, Fig. 9, a similar control regime is considered except that a systemic herbicide is used which reduces bud survival a hundred fold in addition to the reductions listed above. In this instance, effective control of the weed population is achieved (λ = 0.73) and a decline in the infestation is predicted.

In conclusion, if the demographic consequences of control measures are known it is possible to apply these to the model described and therefore predict the effect on population growth rate. If information on crop losses in relation to infestation level is available then the model provides a means of predicting the economic consequences of a control procedure. Hence there is the possibility of using the model to design cost effective programmes of control. This is discussed further by Mortimer et al. (1980).

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