What is the impact of harvesting technology on the spread of new weeds in cropping systems?

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Summary A predictive spatio-temporal modelling framework has been used to simulate the spread of bedstraw (*Galium tricornutum* Dandy) in the southern cropping region of Western Australia. Results indicate a strong impact of seed production and spread rate on the movement of bedstraw seed within and across paddocks. Furthermore, use of a chaff cart during harvest effectively prevents the spread of bedstraw seed. Prediction of the rate of bedstraw spread in farming systems and the effect of farm management practices on that spread is timely, because a decision must now be made on the feasibility of eradication.

Keywords Seed movement, seed catching, bedstraw, spatial model.

INTRODUCTION

Spread of an invasive weed species into areas where it is not present depends primarily on movement of seed. The potential for harvest machinery to spread mature weed seed along tracks has been described by Petzold (1955), Howard *et al*. (1991) and Maxwell (1992). A management strategy to restrict seed movement is seed catching at harvest. This technology is an important component of integrated management systems for many weed species as it can allow for the collection of 40–80% of the weed seed with the chaff fraction during the harvesting process, preventing distribution across the paddock. The seed removed by seed catching is the most mobile fraction of the weed seed and for this reason the value of seed capture is enhanced for invading species relative to the value of reducing seed numbers in the pool as a whole.

A predictive spatio-temporal modelling framework has been used to simulate the spread of an invading species within and between paddocks in a broadacre cropping system, using the example of bedstraw (*Galium tricornutum* Dandy), which is a newly introduced weed species in the southern cropping region of Western Australia (WA). Bedstraw represents a potential threat to cropping as a result of its annual germination pattern, persistent seedbank, easily spreadable seeds, competitive nature and difficulty of control in conventional canola (albeit controllable by herbicides in cereal and legume crops). Prediction of the rate of bedstraw spread in farming systems and the effect of farm management practices on that spread is timely, because a decision must now be made on the feasibility of eradication.

MATERIALS AND METHODS

The model The spread of bedstraw in WA was investigated using a spatial modelling framework built in MATHEMATICA®, which specifically represents the dynamics of crop and weed populations including movement of seed. The temporal component of the modelling framework aims at simulating the life cycle of weeds and crops. This process is affected by the natural mortality of seeds and seedlings, by competition between weeds and crops, and by a range of herbicide and non-herbicide control practices. These factors drive the pattern of weed population change over time.

The bedstraw spatial model is based on a spatio-temporal model for simulating the spread of diseases in crop fields (Diggle *et al*. 2002). In the model the field is divided into equal-sized small rectangular cells, termed 'subregions'. Weed population dynamics is simulated individually in each subregion, whereas seed dispersal occurs both within and between subregions. We assume the main vehicles of seed dispersal to be harvest machinery and grain contamination, even though bedstraw seed may also be livestock-, water- and wind-borne.

Population dynamics data required for the model were collected from the existing RIM (Resistance and Integrated Management) models (Monjardino *et al.* 2003, Pannell *et al*. 2004), literature, trial results and unpublished data. The spatial parameters used in the model were based on data produced for wild radish by Parker (2001). Model parameters are summarised in Table 1.

Limited model calibration has been conducted for the purpose of this analysis, although the model will be submitted to extensive calibration and validation in the future.

Table 1. Key bedstraw parameters used in the default spatio-temporal model

Model parameters	Bedstraw values
Initial seed bank	60 seeds[A]
Annual germination	80%[B]
Seedling survival	25%[B]
Maximum seed produced (max)	10,000 m^{-2}
Seed weight	18 mg[B]
Intraspecific competition factor (*IP*) [C]	0.2
Winter seed pool survival	99%[B]
Summer seed pool survival	99%[B]
Tillage survival at seeding	30%[B]
Seeds caught in the header	70–80%[B,D]
Fraction in straw material from header	5–10%[B,D]
Fraction in chaff material from header	95–99%[B,D]
Region	100 × 100 cell
Subregion (cell)	10 × 10 m
Longitudinal spread factor	16 m
Lateral spread probability	0.2

[A] 20 seeds at each of three locations per 100 ha.
[B] J. Moore, unpublished data.
[C] See Neve *et al*. (2003).
[D] Depending on the crop being harvested.

Analysis design The analysis was conducted for the initial situation where farmers do not yet know that they have bedstraw on their paddocks. Therefore, it was assumed that bedstraw was only 'accidentally' controlled by herbicides usually applied to control other weeds. A four year sequence of canola-wheat-lupin-wheat over 20 years was used. Herbicides applied were glyphosate, trifluralin, simazine, pre- and post-emergent chlorsulfuron, diclofop-methyl, metosulam, 2,4-D amine and diflufenican.

Bedstraw biology is not well known in WA, so a sensitivity analysis on key biological parameters such as maximum seed production was conducted in this study. The values of 10,000 (default) and 7000 seeds m^{-2} have been used for this purpose. A full sensitivity analysis across a range of bedstraw parameters will be conducted in the near future. Longitudinal spread was assumed to follow a Cauchy Distribution with a default spread parameter of 16 m as found for wild radish (Parker 2001) and also 32 m to allow for the possibility that bedstraw is retained longer in the header due to its sticky nature. Finally, we have investigated the impact of seed catching at harvest on the spread of bedstraw seeds in the worst case scenario: 10,000 seeds m^{-2} and high spread (32 m). Therefore, five scenarios were investigated.

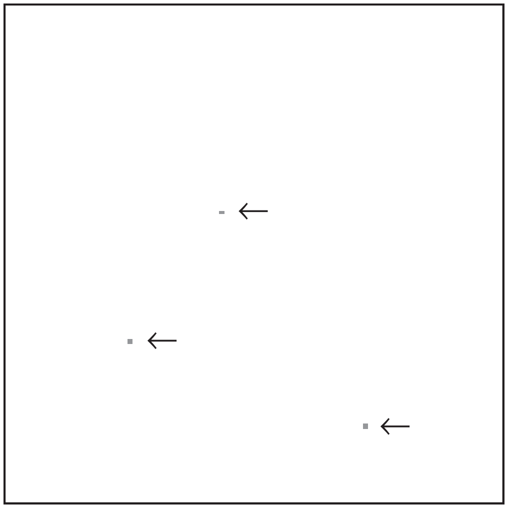


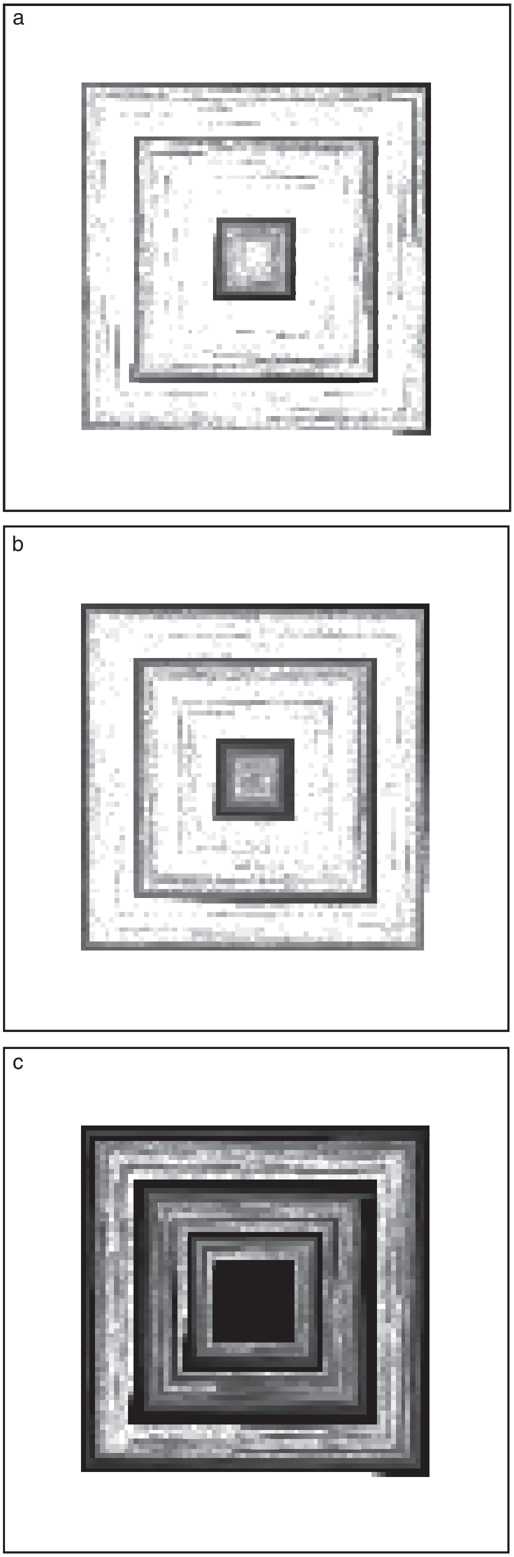
Figure 1. Initial infested cells with 20 bedstraw seeds each (arrows indicate location).

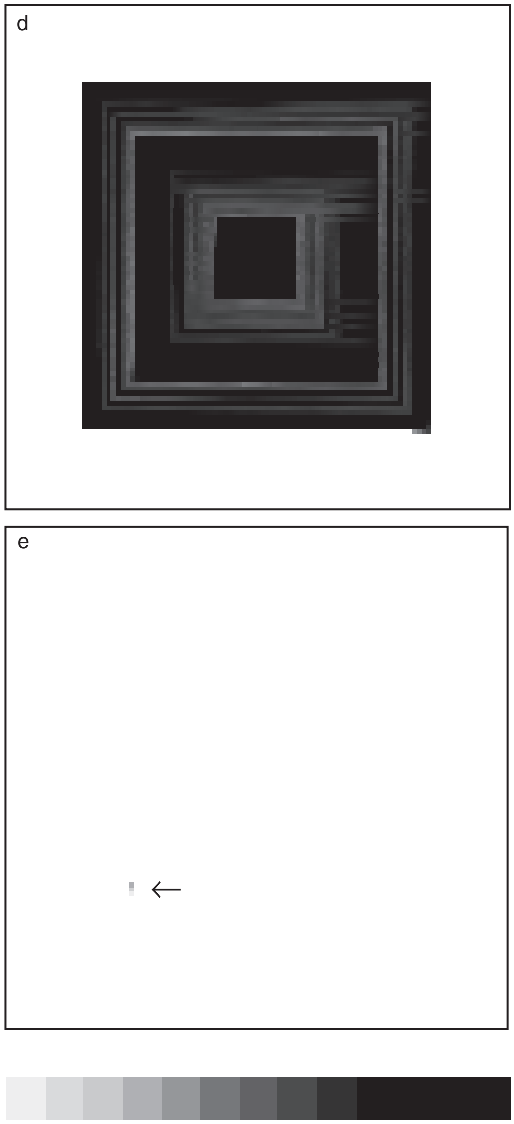
The model was set for a region (paddock) of 100 × 100 cells (totalling 100 ha) with subregions (cells) of 10 × 10 m to accommodate the 10 m wide harvesting headers commonly used in WA. All runs were initialised with three infested cells containing 20 bedstraw seeds each, randomly located as shown in Figure 1. A probability of lateral spread between header rows of 0.2 per year was assumed along the spiral header track.

RESULTS

The model was run over 20 years, producing a dynamic picture of the spread of bedstraw seed for each scenario. Figure 2 shows the spread of bedstraw seed in the 20th year across all five scenarios (except scenario *e*, for which the 6th year is shown as there were no seeds in the second half of the modelled period).

The results indicate that the rate of bedstraw spread varies significantly according to seed production and rate of spread. There is also clear indication that the use of a chaff cart during harvest effectively prevents the spread of bedstraw seed, with its population eradicated after eight years in this scenario. The high density of bedstraw seed observed across scenarios *a* to *d* does not correspond to the density of bedstraw plants at maturity. The maximum number of mature bedstraw plants per 10 × 10 m cell in year 20 was found to be 86, 182, 3357 and 6631 plants for each scenario, so the darkest parts of the map still only have 0.9, 1.8, 33.6 and 66.3 bedstraw plants m^{-2}, respectively.





Key: Shades correspond to a 10 × 10 m cell containing 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000, and 10,000 seeds respectively.

Figure 2. Distribution of bedstraw seed after 20 years assuming: maximum seed set (max) of 7000 seeds m^{-2}, low spread (16 m) and no seed catching at harvest (a); max of 7000 seeds m^{-2}, high spread (32 m) and no seed catching at harvest (b); max of 10,000 seeds m^{-2}, low spread (16 m) and no seed catching at harvest (c); max of 10,000 seeds m^{-2}, high spread (32 m) and no seed catching at harvest (d); and max of 10,000 seeds m^{-2}, high spread (32 m) and seed catching at harvest (e) (arrow indicates location).

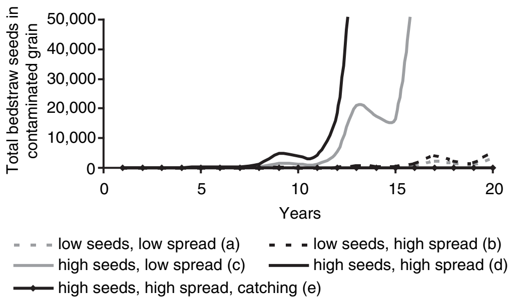


Figure 3. Total bedstraw seed in contaminated grain for scenarios *a* to *e*.

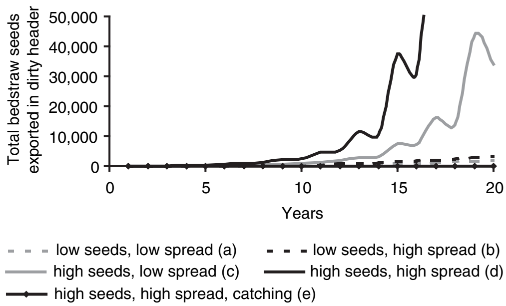


Figure 4. Total bedstraw seed remaining in the header at the end of harvest for scenarios *a* to *e*.

These results are complemented by Figures 3 and 4, which represent the total of bedstraw seeds in contaminated grain and the total of bedstraw seeds remaining in the header at the end of harvest each year for each of the five above scenarios over 20 years. The amount of bedstraw seed exported in the crop grain and remaining in the header was greater in scenarios *d* and *c*, indicating that seed production is the determining factor in those cases rather than seed spread. Little bedstraw seed was removed from the paddock when seed catching was used.

DISCUSSION

Results from the model indicate that the uncontrolled spread of bedstraw in the southern cropping region of Western Australia may be a real issue in a situation of high seed production and high rate of spread. Even where seed production is assumed to be lower, bedstraw persists and becomes more widely spread within the paddock, and substantial amounts of seed leave the paddock in both grain and in the header. However for the initial conditions examined here, bedstraw would be eradicated after eight years if seed catching were to be consistently used during harvest. Further modelling work will be conducted to help predict the effect of appropriate farm management practices on the spread rate of bedstraw in farming systems.

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