Use of cellular automata modelling approaches to understand potential impacts of GM grasses on grassland communities

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Keywords: cellular automata, strategy theory, risk assessment

Introduction In order to predict the potential unintended ecological impacts of genetically modified (GM) grasses, we must understand how the engineered traits, in this case herbicide resistance, are expressed in an ecological context. It would be a daunting task to experimentally evaluate the full multiplicity of potential pair-wise interactions between GM plants and native plants under a broad variety of actual environmental conditions. We have employed the modelling methodology of cellular automata (CA), where a plant's distribution within a two-dimensional environmental grid is determined by rules relating to phenomena such as seed dispersal, clonal expansion and interactions with adjacent plants. We have used CA simulation to model interactions between GM grasses and the natural environment by describing the plants and the effect of the GM trait in terms of plant functional types. This approach takes the external factors which limit the amount of plant material present in any habitat and classifies them into two categories: (1) stress, defined with regard to the availability of nutrients and (2) disturbance, which refers to the destruction of plant material. The ecological characteristics of all the plants can be described based on three functional types C (competitor), S (stress-tolerator) and R (ruderal) as determined by their quantifiable physiological relationships to stress and disturbance. By ascribing the large number of plant ecological characteristics to a smaller number of functional types the problem, of describing how the engineered trait of herbicide resistance is expressed in an ecological context, becomes tractable.

Materials and methods All simulations involve two-dimensional cellular automata consisting of a 50 X 50 array of discrete cells. At any point in time each cell can contain any number of resource units but only one plant occupant. According to the instructions in the rule base each cell's state is updated individually in discrete time steps (iterations) and is determined by the previous state of the cell and that of its immediate neighbours.

Resources (per cell) / Probability of disturbance

	0.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6
0	S	S	S	CS	C	C	C	C	C	C
0.07	S	S	CS	C	C	C	C	C	C	C
0.14	SR	SR	CSR	C	C	C	C	C	C	C
0.21		SR	CSR	CSR	C	C	C	C	C	C
0.28		SR	CSR	CSR	CSR	C	C	C	C	C
0.35		R	SR	CSR	CSR	CSR	CR	CR	CR	CSR
0.42			R	CR	CR	CR	CR	CR	CR	CR
0.49			R	R	R	R	R	CR	CR	CR
0.56					R	R	R	R	R	R
0.63										

(a)

Resources (per cell) / Probability of disturbance

	0.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6
0	S	S	S	CS	C	C	C	C	C	C
0.07	S	S	S	S	C	C	C	C	C	C
0.14	S	S	S	S	C	C	C	C	C	C
0.21	S	S	S	S	S	C	C	C	C	C
0.28	S	S	S	S	S	S	S	S	S	S
0.35	S	S	S	S	S	S	S	S	S	S
0.42	S	S	S	S	S	S	S	S	S	S
0.49	S	S	S	S	S	S	S	S	S	S
0.56	S	S	S	S	S	S	S	S	S	S
0.63	S	S	S	S	S	S	S	S	S	S

(b)

Results C-S-R space; each grid cell contains the mean dominant plant type for a separate treatment of the 'all types all conditions' experiment. The disturbance axis of the matrix is analogous to the concentration of herbicide. Equal numbers of all plant types (35 of each) were planted into a 50 by 50 grid. Runs lasted for 1000 iterations; each point represents the mean of 20 replicate runs. Bold capitalised entries denote a plant monoculture. (a) C-S-R space for a community of all seven plant functional types. (b) C-S-R space for the seven plant types including a genetically modified plant of functional type S (indicated by a shaded grid cell).

Conclusions A conclusion that can be drawn from this is that the engineered trait of herbicide resistance preferentially benefits those plants that are suited to the opposing environmental driving factor. In this case the resistance is to the disturbance of herbicide, a factor that most affects slow growing stress tolerant plants. They would most benefit from a protection from disturbance rather than ruderal plant types that already have a strategy for 'overcoming' disturbance.

Reference

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