# A macroecological perspective of herbicide resistance in weeds

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**Summary** Current knowledge of herbicide resistant weeds has been built over many decades through painstaking case studies examining the mechanisms of herbicide resistance of individual weeds. Considerable data now exist on the frequency of herbicide resistance to different modes of actions in different weeds species worldwide comprehensively captured in the Herbicide Resistant Weed Database. These data now permit a macroecological perspective addressing broader generalisations and synthesis of key global patterns in herbicide resistance. Three recent examples illustrate the value of a macroecological approach: a) the role of weed species traits in the likelihood of herbicide resistance evolution; b) patterns in the occurrence of multiple resistance across different herbicide modes of action; and c) global economic drivers of the number of herbicide resistant weed worldwide. Boosted regression tree analysis has highlighted that species traits associated with rapid evolution (chromosome number, self-incompatibility) are more closely linked to herbicide resistance than traits normally associated with weediness such as annual life-history and self-compatibility. However, the most important trait was the prevalence of the species, the more prevalent the more likely to be herbicide resistant. Hierarchical cluster analysis distinguished three primary clusters of modes of action within which multiple resistance is most likely. A clear message when mixing herbicides is to select between rather than within clusters. Finally, an information theoretic analysis of the numbers of herbicide resistant weeds in different countries pointed out that in many cases numbers are likely to be underestimated due to low research capability in many countries and in general also simply reflects the time since herbicide resistance was first detected. The intensity of herbicide use was also important, but the sampling effects suggest the level of herbicide resistance is underestimated worldwide. The foregoing illustrates that macroecological approaches and machine learning techniques have considerable potential to provide insights into herbicide resistance.

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