New approaches to clover breeding

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Introduction White clover (*Trifolium repens* L.) and red clover (*T. pratense*) are the major forage legumes of temperate pastures. Breeding efforts have focused on overcoming the constraints to productivity and reliability in this species and thereby optimising their contribution to mixed swards. In recent years there has been an increased emphasis on livestock production and the efficient utilisation of forage material in the rumen. In this paper we report on a shift in the aims of forage legume breeding at IGER, building on a strong agronomic platform but giving greater consideration to the environmental footprint of our varieties and the contribution that they can make to the quality of meat and milk.

White clover In white clover we are focusing on reducing phosphorus and nitrogen leaching. We have shown variation in the field for ability to yield well at reduced P levels and are relating genotypic variation to leaching propensity. We are also approaching the problem of nitrogenous pollution by improving the efficiency of protein utilisation in the rumen. Protein levels in agronomically superior individual plants show considerable, hitherto unsuspected, variation implying scope for selection to promote a balanced supply of energy (primarily from companion grasses) and protein. In collaboration with the Centre for Ecology and Hydrology at Bangor, UK we are also evaluating ozone tolerance in relation to white clover agronomic performance.

Red Clover The red clover breeding programme at IGER recommenced in 1998 after an interval of more than twenty years; there are considerable opportunities for improvements in yield, persistency, grazing tolerance and pest and disease resistance. Nonetheless, work on this species too is bringing into focus the needs of a more environmentally friendly livestock sector. Thus, we are developing lines with enhanced protein protection, due to increased levels of the enzyme polyphenol oxidase (PPO), which have the potential to reduce nitrogenous pollution from the silo. Ongoing work in collaboration with animal scientists at IGER is exploring variation in polyunsaturated fatty acid profiles in red clover and their consequences in terms of meat and milk quality.

Breeding strategies and methods The evaluation of breeding lines through the ruminant animal or analysis of impacts on the environment poses considerable logistical challenges to classical approaches to improvement, necessitating novel strategies and methods. Molecular marker approaches are being developed consequent to the creation of the first molecular genetic map in white clover (Jones *et al*. 2003) in a collaboration between IGER and the Plant Biotechnology Centre in Victoria, Australia. Isobe *et al.* (2003) recently reported the development of the first map in red clover. The use of marker assisted selection (MAS) offers the possibility of making gains in some of the traits described above and the transfer of genetic and genomic information, such as sequence information and transcriptome arrays, from the 'model legumes' *Medicago truncatula* and *Lotus japonicus* will greatly facilitate this process. At IGER, we are using simple sequence repeat markers derived from *M. truncatula* expressed sequences to assess their utility in white and red clover and determine the degree of synteny between these three species. While the evaluation of clover content and quality of mixed swards is now carried out by near infrared reflectance spectrophotometry (NIRS) and the combined application of NIRS and MAS through multivariate statistical methods offers considerable potential for the future.
The scale at which environmental impacts such as reduced pollution of waterways are manifest is beyond that of the small plots traditionally used to assess clovers under grazing or cutting regimes. Evaluation and improvement for these traits and on this scale will require not only the use of MAS but also a combination of high resolution environmental monitoring and modelling approaches.

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