The key aim of a ‘public good’ plant breeding programme is to address the challenge of food security whilst reducing the impact of food production on the environment, i.e., ‘sustainable intensification’. As part of this, a considerable focus of our research is on mitigating climate change through reducing greenhouse gas emissions and enhancing carbon sequestration. Substantial effort has been given to the development of new grass varieties that reduce the need for nitrogen fertiliser and increase the efficiency of plant protein utilisation in the rumen of sheep and cattle. Clearly, forage legumes have an important role to play in the future of grassland production systems as they can take atmospheric nitrogen and convert it into a form usable by plants (and through them, animals), dramatically reducing the need for nitrogen fertiliser. Among grain crops, oats are widely considered as a ‘sustainable cereal’, displaying superior nitrogen use efficiency and weed suppression compared to wheat and barley. Work at IBERS has also shown that changing the oil composition of oats is a possible route to reducing methane emissions from ruminants.

Breeding for stress tolerance

Agronomically, the ryegrasses, and especially perennial ryegrass, provide UK farming with the optimal growth and forage quality characteristics required for sustainable livestock gains and milk production, as exemplified by IBERS’ high sugar ryegrasses. These varieties also provide environmental benefits through efficient N use, though both their persistency and yield may be compromised by a changing climate with higher summer temperatures and more frequent and prolonged drought periods. To combat these scenarios, genes for drought resistance are being transferred to ryegrass through precision breeding. Without recourse to use of GM technologies, traits are being introduced from closely related fescue ecotypes selected from naturally adapted grasslands in southern Europe and North Africa. Outputs from these plant breeding programmes were originally tested and selected under simulated 3-month drought periods with temperatures in excess of 40°C. Selected lines are now undergoing field trials.
under UK climate conditions and at sites in central France and New Zealand where hot dry summers normally prevail. Recent changes to EU legislation provide opportunities to exploit these ryegrass x fescue hybrids, termed Festulolium, commercially throughout Europe, provided the lines are achieved through natural breeding methodologies such as those used currently at IBERS.

As hybrids, ryegrass and fescue species exchange genes at very high frequencies, enabling new grass cultivars to be redesigned to combine the attributes of both parent species. Central to this process has been the use of a unique mapping population, where each perennial ryegrass chromosome was in turn replaced by its meadow fescue equivalent and, subsequently, each fescue chromosome ‘dissected’ by inclusion of alternative ryegrass genes of different number and location. This mapping strategy has allowed ryegrass/fescue gene complements to be studied in detail so that their optimal genome combinations are selected. Recently, a major strategy has been to improve root growth in ryegrass in response to increased soil water deficit, with ryegrass/fescue genes on chromosome 3 found to be particularly effective and therefore targeted. Using the same breeding approach, new root designs for improved N and P uptake are being developed to improve nutrient use efficiency, with major advances being made in forming root systems enabling improved soil structure and porosity. An IBERS-bred Festulolium cultivar both ameliorates soil structure and aids soil water retention by providing a larger reservoir of water accessible to the roots at times of low or no rainfall. An added benefit is that this new cultivar also enhances flood prevention during times of excessive rainfall by facilitating a well-defined soil structure to form around the roots, aiding porosity and restricting soil compaction (Figure 1).

Trifolium hybrids

White clover (Trifolium repens L.) is the most widely grown forage legume of temperate grassland systems and is predominantly sown in pastures with perennial ryegrass (Lolium perenne L.), producing a high quality forage that can be grazed by sheep or cattle. White clover breeders have historically focused on improving a range of important traits which, together, lead to increased persistence and reliability of clover content in a mixed sward. Although considerable variation is available for the improvement of many of these traits, there are some desirable attributes where variation is limited. For example, only limited variation is present for drought tolerance, a characteristic which has long been a major breeding objective in more arid areas and which is becoming increasingly important in the UK due to the likely effects of climate change. To overcome this lack of genetic variation, the IBERS white clover breeding programme has been seeking to exploit the additional variation that exists within other species of the Trifolium genus (Figure 2).

Genes for drought tolerance have been introduced into white clover through the development of interspecific hybrids between white clover and the drought-tolerant rhizomatous species, Trifolium ambiguum M. Bieb (Caucasian clover). This is a very persistent forage legume that spreads via underground stems (rhizomes), a feature which may also contribute to its excellent performance under semi-arid conditions. Backcross hybrids between white clover and T. ambiguum have been produced that are essentially white clover-like in appearance but are able to maintain a higher relative water content and leaf water potential at soil moisture deficit levels where standard white clover cultivars exhibit significant signs of moisture stress (Figure 2). The first medium-leaved white clover variety from this programme has now been entered into official National List trials and further varieties across the different leaf size categories are currently in development.

The work described on water stress is only one example of how modern plant breeding approaches can be used to address the many challenges facing agriculture in the 21st century. IBERS’ strong commitment to ‘public good’ plant breeding is demonstrated by significant capital investment at the Gogerddan site and plans to increase our role in the training of the next generation of plant breeders.