DIVERSIFOOD – Embedding crop diversity and networking for local high quality food systems

*One of the key opportunities for, and expectations from, organic farming is to reverse the trend of agricultural standardisation and to embed more species and genetic diversity into farming and food systems. This year marked the end of the four-year European research project DIVERSIFOOD, 'Embedding crop diversity and networking for local high-quality food systems'. Principal Crops Researcher **Ambrogio Costanzo** looks back on what's been achieved and learned in this international and participatory project on cultivated biodiversity 'from the seedbank to the plate'.*

How much diversity do we use?

Throughout history, thousands of plant species have been domesticated and used in agriculture. Most of them are now underutilised. Forgotten, untapped plant genetic resources have often been the object of efforts of conservation, either *ex situ*, i.e. in seedbanks, where seed and reproductive material is stored securely, or *in situ*, i.e. being actually kept in cultivation in their supposedly original areas and systems, also with the help of legal and marketing frameworks such as 'conservation varieties'. DIVERSIFOOD has attempted to go beyond mere conservation of diversity and towards innovation, considering these genetic resources as a key asset to restore agricultural diversity and thereby fuel successful transitions to agroecological food and farming systems. This has entailed a 360-degrees approach to systematise the process of bringing underutilised genetic resources from being bunches of seeds in seedbanks to become actual crops and, ultimately, food.

ORC intern Anne-Lise Villard assessing rivet wheat in Sonning last summer with Ambro (deep into the canopy).

What are underutilised crops?

At times, to be effective in practice, an effort of theory is needed beforehand. In DIVERSIFOOD, the first step has been to conceptualise what underutilised genetic resources are, in a way that pointed us directly to address specific challenges and to undertake specific processes. In fact, the 'working definition of underutilised crops', does not focus on the plants. It rather focuses on the process of building opportunities across a wide range of neglected or unexplored resources.

In the DIVERSIFOOD project, an underutilised crop was defined as:

A plant genetic resource with limited current use and potential to improve and diversify cropping systems and supply chains in a given context.

Agreeing on this general definition enabled us to highlight three main processes, according to which 'underutilised status' a given genetic resource starts from in a given context.

1. **Introducing 'outsider species'.** This challenge applies whenever there is a need or opportunity to shift a cultivation areal, either across a geographical discontinuity (e.g. Quinoa from South America to Europe) or extending the borders of the original cultivation areal (e.g. moving Chickpeas and Buckwheat northwards). In many cases, the primary interest can arise from professional or home growers/gardeners. In other cases, it can even be from climate change, with likelihood of warmer and longer growing seasons, that the opportunity (or the necessity) to introduce new species where they are not usually grown arises. Examples that have been explored in DIVERSIFOOD are growing chickpeas in the UK or extending buckwheat cultivation northwards in Finland.
2. **Reviving 'old, forgotten species'.** The starting point is to understand why these species, e.g. old minor cereals, have been 'forgotten', and why it has been so easy to 'forget' them. Although specific answers are related to specific cases, abandonment is generally an overall result of the Green Revolution, i.e. the widespread diffusion of high yielding varieties and related 'technological packages' starting post-war. This has led to a standardisation of environments, cropping techniques, processing and supply chains, that most of these 'abandoned' species did not fit into. A typical example in DIVERSIFOOD has been rediscovering accessions of rivet wheat (*Triticum durum* subsp. *Turgidum*) in France, the Netherlands and the UK.
3. **Using 'neglected germplasm of common crops'.** Open pollinated varieties (OPs) of currently hybrid-dominated crops which went through the same process of abandonment as 'forgotten species' during the Green Revolution. Increasing the use of OPs would broaden the genetic diversity of these common crops and facilitate local adaptation. Reviving these germplasms and exploring new genetic structures such as genetically diverse populations could help overcome agricultural standardisation, giving back marginal areas, artisanal processing and low-input farming significant chances of successful sustainable development. Examples that have been explored in DIVERSIFOOD are testing OPs of Broccoli (in Switzerland, France and the Netherlands) or Maize (in Portugal and in Cyprus).

Embedding more diversity in farming and food

Currently, with highly standardised cropping systems, having a diversity of genetic resources available in genebanks is no more than a starting point towards their successful use. The whole process of embedding a greater diversity of genes and species in farming and food systems needs to be considered, and often these systems need to be developed from zero. To address this challenge, DIVERSIFOOD has carried out work in two parallel streams. On the socio-economic side, we have engaged with communities (farmers, processors, consumers) already working with 'underutilised crops', to understand the key drivers of success and the barriers they face. One example is the value chain developing around the ORC Wakelyns Population wheat (a typical example of 'alternative germplasm of a common species'), from seed merchants to growers and to bakers, namely Kimberley Bell and the Small Food Bakery in Nottingham (see p14-17 and ORC Bulletin no. 125, p. 14).

In parallel, on the agronomic and biological side, researchers and farmers have sourced and exchanged small quantities of seed of many different accessions and species, to test them in specific cropping systems aiming to understand their strengths and weaknesses.

From the seedbank to the field

ORC has coordinated a series of experiments conceived as an exploration of genetic resources in specific, local agro-environmental or market contexts, often linked with farmer initiatives. Nine species have been tested with hundreds of accessions in 33 different trials across Europe. Seeds have been sourced from a variety of both informal and formal, *ex situ* and *in situ* collections, such as those maintained by the partner ProSpecieRara in Switzerland, and from public seedbanks, such as the John Innes Centre in the UK. This created a unique merging and on-farm deployment of genetic resources from very different sources. A lot of information has been generated in these experiments, but perhaps the most important highlights are the lessons learned in terms of process and methodology, including the most precious learning of all: the mistakes.

DIVERSIFOOD

The DIVERSIFOOD project aimed to enrich cultivated biodiversity by testing, renewing and promoting underutilised genetic resources. Through a radical multi-actor approach, with the active engagement of communities of farmers, processors and researchers, it has proposed an innovative way to bring genetic resources in use also aiming to encourage a new food culture. The project has involved 21 partners from 12 European Countries, from Norway to Cyprus, from Portugal to Finland, over four years between March 2015 and February 2019.

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Describing the genetic resources

What do the plants look like? How to identify or simply describe them? Virtually every cultivated plant species is the object of publications and guides to successfully describe the genetic resources in terms of key characteristics. However, many germplasm screenings usually stop once the plants are carefully described in terms of their appearance, whereas little useful, consistent information is available in terms of how the plants can perform as crops in a practical farming context.

In the DIVERSIFOOD trials, all tested genetic resources have been described, yielding two main comments:

1. When growing underutilised genetic resources, certain traits that during modern breeding had been lost reappear. These also include undesirable traits that might have played a role in the abandonment of certain phenotypes. A typical example is the brittle rachis in einkorn that can generate huge grain losses prior to, or during, harvest. Another is the extreme straw height of certain winter cereals like rivet wheat (*Triticum durum* subsp. *turgidum*), that creates problems of lodging (although rivet wheat accessions with similar straw height were found to differ significantly in terms of lodging susceptibility).
2. Many genetic resources show considerable within-crop phenotypic heterogeneity. This can be linked to their genetic structure, them being landraces or OPs or composite cross populations. However, this can also result from intentional or even accidental mix-up, as we observed in certain entries of rivet wheat that included considerable amounts of bread wheat (that was probably not supposed to be there).

Assessing performance of genetic resources

The key challenge in DIVERSIFOOD, beyond describing the appearance of the plants, was to understand how these plants behave in specific agroclimatic conditions and cropping systems, what benefits they could offer, what drawbacks can they entail, and what the potential would be to introduce them at a commercial scale. This meant to carefully evaluating their performance.

Evaluating performance of underutilised genetic resources is easier said than done. Considering the range of species tested, from tomatoes to wheat and buckwheat, and the diversity among the 33 specific contexts of evaluation, we were stimulated (and forced) to understand and highlight what performance evaluation is in general, so as to make learning useful to whoever wants to engage with whichever other crop in other contexts. What is a crop's performance? How to unpack it? How to measure it? Interestingly, this reasoning was not done beforehand. On the contrary, it has accompanied step by step the experimentation in a unique, collective learning-by-doing process. The resulting framework is shown in Fig. 1. On one side, we need to consider the '**predictors of performance**':

1. Those mostly borne by the plant's DNA, i.e. its morphology (the 'shape' of the plant) and phenology (the 'timings' of its growth cycle), and
2. Those embedded in the cultivation environment.

On the other side, resulting from the interactions between the two above categories of 'predictors', we need to consider the three main '**dimensions of performance**':

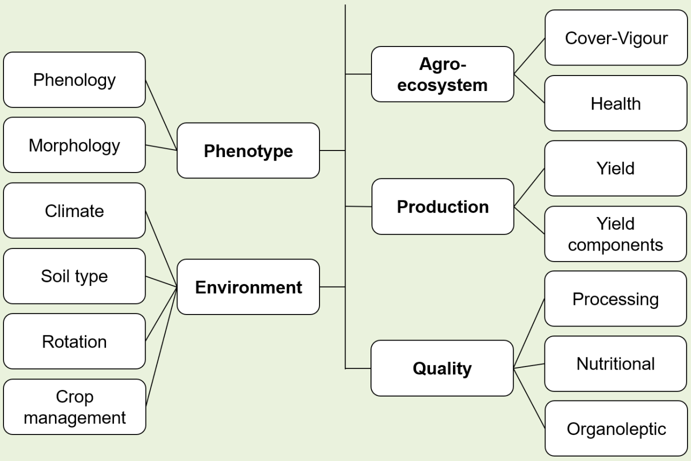


Figure 1: The components of crop performance

3. The **agro-ecosystem performance**. How does the crop fit into the growing environment? Does it pre-empt the space and resources or does it get overwhelmed by weeds? Is it too much affected by pests and diseases?
4. The **productive performance**. How much production, and in which form and timings, can the crop provide? Is harvest manageable or difficult?
5. The **quality performance.** What end-use is possible with the crop's produce? What kind of processing is possible or needed? Does it have a nutritional added value? Does it taste good?

Readers can imagine how difficult it can be to consistently provide an answer to all the above five points at once. Imagine a cereal crop producing an extremely nutritious and tasty grain but limited by a ridiculously low yield. Or a crop that has a perfect fitness to the growing environment, no diseases, high yield, but a disgusting taste. I invite the readers to keep reading through and see what sort of overall conclusions we reached.

Agroecosystem performance was evaluated from different directions but the two aspects that we suggest as the most practically useful to look at are (1) the crop 'cover', as a proxy of its fitness, ability to capture resources including light and space and to compete against weeds, and (2) the 'health', i.e. the overall response to pests, pathogens and abiotic stresses. The overall outcome across all DIVERSIFOOD experiments and species confirms that 'underutilised genetic resources agroecosystem performance of the same genetic resource can vary greatly depending on where it is grown and must therefore be looked at on a very local scale. In ORC Bulletin no. 123, pp. 4-5, we showed how underutilised relatives of wheat, emmer, einkorn and rivet wheat, thrived on a poorly-drained heavy blue clay in the North Wessex Downs, where commercial wheat was not a viable option (Fig. 2). As obvious as it might seem, this reinforces the importance of deploying and testing genetic resources in multiple farms rather than on research stations. Or to use a centralised research station to simulate different growing conditions such as different rotational positions and/or tillage systems (Fig. 3).

From the perspective of **productive performance**, the DIVERSIFOOD experiments highlighted a, perhaps expected, two-fold trend: yield of 'underutilised genetic resources' can be a serious limiting factor, as the tested material can be either low-yielding or difficult to harvest, but, in many cases, can be a relief for marginal conditions. Species such as einkorn, emmer or rivet wheat can thrive where their

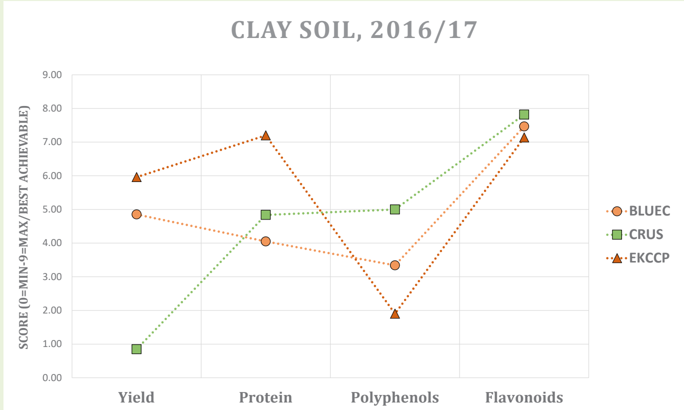


Figure 2: Performance profiles in terms of yield, protein and anti-oxidant compounds (polyphenols and flavonoids) of a rivet (BLUEC), and einkorn (EXCCP) and a commercial wheat (CRUS) grown by ORC on a clayey soil in Doves Farm (Wilts) in 2016/17. The y axis indicates an overall performance score fom 0 to 9. Einkorn and rivet yield much more than wheat.

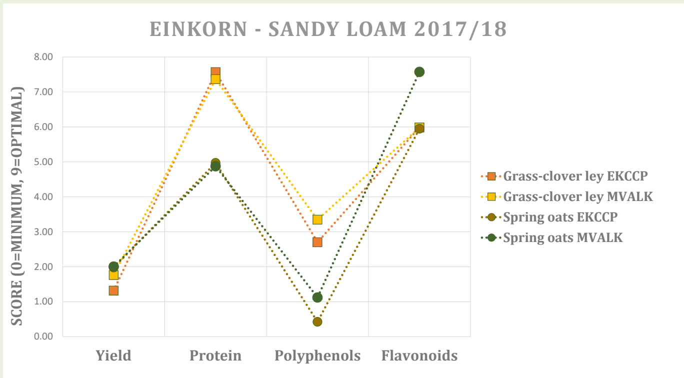


Figure 3: Performance profiles in terms of yield, protein and anti-oxidant compounds (polyphenols and flavonoids) of two einkorn accessions grown by ORC on a sandy loam soil in the University of Reading Crops Research Unit experimental farm in Sonning in 2017/18. Yield was low, but protein and polyphenols content were higher when einkorn was grown after a grass-clover ley than when it was grown as a second cereal after spring oats. Figure from the DIVERSIFOOD database.

commonly grown closest relatives (e.g. durum or bread wheat) are not a viable option. This is one of the key benefits expected from underutilised crops: they can be a valuable resource for more marginal land.

Quality performance was evaluated under different aspects namely (i) processing quality, (ii) nutritional and nutraceutical quality, (iii) organoleptic quality. A diversity of crops triggers a diversity of products that, in turn, need adaptation in both the processing and the methods and concepts used to assess their quality. Grains from minor cereals are not necessarily suited to industrial milling but provide an opportunity for artisanal millers and bakers, whose processing methods are more flexible and adaptable to the raw material, to add value to highly nutritious grains. Broccoli OPs have shown a higher concentration of health-promoting compounds (e.g. glucosinolates, proved to have anti-carcinogenic properties) than mainstream F1 hybrids, without necessarily a lower yield (Fig. 4). The diversity in shape and taste of the florets (glucosinolates are actually amongst the drivers of broccoli's bitter taste) makes them more suited to direct marketing or farmers' markets than supermarket sales, at least for the time being.

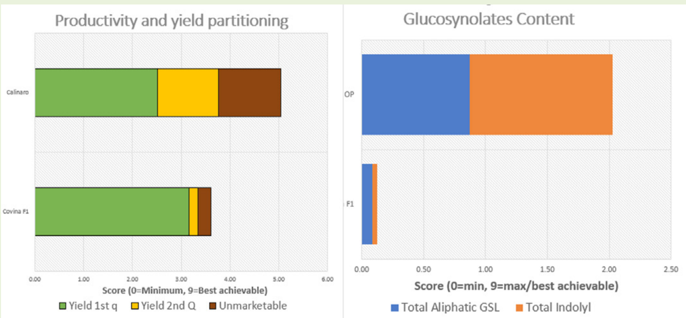


Figure 4: Comparison between the performance of an open pollinated broccoli (above) and a hybrid broccoli (below). The left shows that the OP yielded more than the hybrid, but the yield advantage was mostly made of second-class (yellow bar) and umarketable florets (brown bar). The right shows that the content of two categories of glucosinolates (health-promoting compounds) was higher in the OP than in the hybrid (data from an experiment in Switzerland in 2016, courtesy of FiBL). The horizontal axis indicates an overall performance score from 0 to 9. Figure from the DIVERSIFOOD database.

From the field to the table

ORC looked at eight case studies, four on vegetables and four on cereal species, considering the perspectives of different actors from farmers to consumers, and generating pointers that need to be carefully considered when aiming to create novel value chains that embed diversity.

1. At an early stage of value chain development, the commitment to preserve and increase genetic diversity can struggle in establishing market interest and demand. Opportunities arise from the story behind the product becoming an added value in itself. However, it is essential to build an evidence base behind the story to substantiate marketing claims.
2. Once the value chain starts developing, several initiatives show that problems arise with meeting, instead of creating, a demand that can grow quite fast. Lower yields, unsteady supplies and wastage in processing can be serious limiting factors.
3. To make these value chains grow further, several of the initiatives studied highlight how successful it can be to move beyond the initial value chain (generally oriented around fresh vegetables, bread and pastas) to more innovative products and services, thereby expanding market opportunities.
4. Some more developed case studies are reaching markets through collaboration with other stakeholders, for example multiple retailers that have skills and resources to facilitate sales.
5. It is generally thought that to market underutilised crops one must select either a national/international marketing strategy, or a local/decentralised strategy. However, these two strategies can work alongside each other, and complement each other, offering potential to diversify marketing channels and reach new consumer groups.
6. Value creation around a higher diversity of crops often starts with a bottom-up approach from small-scale producers. This can have drawbacks; for instance, when many small-scale producers are involved, coordination of the collection of produce would be beneficial, but that involves complexity and requires an actor to take responsibility, which can be challenging in, often fragmented, networks.

The diversifood database

In research, making information available and useful is the 'elephant in the room'. Even more so nowadays, as we are bombarded by claims through all sort of, increasingly uncontrolled, social and conventional media. Data are often the most overlooked piece of information, however data are the building block of information and should be accessible.

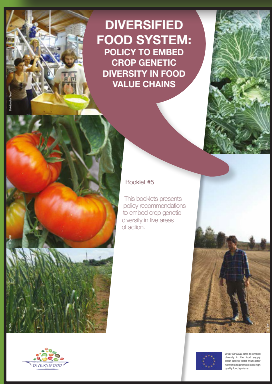
To merge results from all the experiments on 'underutilised crops' in a unique, available, accessible repository, the ORC team has generated the 'DIVERSIFOOD database'. Unlike many existing databases on genetic resources, mostly focused on descriptions and generic information, this tool aims to provide an information basis on actual performance data of genetic resources, with minimally filtered data.

The DIVERSIFOOD database is currently no more than a proof-of-concept of how context-specific information can be stored and made accessible. We hope to see it developing as a common resource to enable communities engaged in testing and using a diversity of plant genetic resources to collect, share, and base their decisional processes on, structured evidence.

The DIVERSIFOOD database is currently downloadable from the DIVERSIFOOD website. You will find the Excel database and a PDF report including a user guide and factsheets from all trials at: http://www.diversifood.eu/diversifood-database/

References and useful resources

1. **DIVERSIFOOD innovation factsheets** A series of 25 'practice abstracts' covering all aspects of embedding diversity in sustainable farming and food systems, including the definition of underutilised crops, factsheets on rivet wheat in France, einkorn in Hungary, farmers' rights, community seedbanks, marketing strategies and much more. All downloadable at: http://www.diversifood.eu/publications/innovation-factsheets/
2. **DIVERSIFOOD booklets.** A series of seven booklets covering practical aspects of research, farming, marketing and policy around increasing crops diversity in the farm and in the supply chain. These include the *Guide to participatory experiments on underutilised genetic resources* (also available at http://orgprints.org/35259/) and *Case studies of the marketing of products from newly bred lines and underutilized crops* (http://orgprints.org/34456/), both edited with contributions from ORC. All booklets are downloadable at: http://www.diversifood.eu/publications/booklets-and-reports/



3. **DIVERSIFOOD Congress,** held in Rennes (FR) on the 10th -12th December 2018. Full proceedings are available at https://symposium.inra.fr/diversifood2018/. Presentations from the DIVERSIFOOD congress and the DIVERSIFOOD forum with policy makers and stakeholders held in Brussels on the 11th April 2018 are available at: https://www.slideshare.net/diversifoodproject/presentations