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CROP DIVERSITY & AGRONOMY

(R)evolutionary wheat populations

Adaptable, stable, or both?

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ABSTRACT

Wheat cropping forms an important component of organic rotations and it is therefore critical to identify varieties that are well adapted to organic growing conditions. However, organic conditions among farms are notoriously varied, and climate change adds further to this variability. A potential solution to these challenges is to grow crops with a high genetic diversity, composed of many different types of plants, as opposed to commonly used varieties in which every plant is virtually the same. Thanks to their diversity, these crops, called 'populations', can buffer against the environmental variability through compensatory processes as well as adapt to differentiated conditions by natural selection over time. In 2001 started testing and developing this concept with a set of initially three winter wheat populations. These were made from crossing various varieties; the crossing resulted in three genetically diverse composite cross populations (CCPs), designed for high baking quality (Q), high yield (Y), or as an all-rounder (YQ). Initial field trials demonstrated a small yield advantage of the CCPs over the mean of the parent varieties, and a gain in yield stability. Several farmers, bakers, and breeders were involved in the research, and their enthusiasm for this approach led to a substantial expansion of the experimental CCPs grown in the UK. In response to this development and similar pressures on the continent, a derogation of European seed legislation was allowed for a temporary experiment on the marketing of seed of heterogeneous cereals. This experiment has led to the recognition of organic heterogeneous material within the new European Organic Regulation 2018/848.

Figure 1 Two plants from the same population at Wakelyns Agroforestry. Credit: T. Döring

INTRODUCTION

Most cereal crops nowadays tend to be uniform stands where each plant is genetically similar if not the same. Uniformity is in fact a legal requirement for the seed of major cereal species, such as wheat, to be commercialised. Current EU seed legislation requires registered varieties to comply with tests of Distinctiveness, Uniformity and Stability (DUS) over time and space.

Wheat is a typical example of a crop that yields remarkably lower in organic compared to non-organic farms, and this is in part linked to inappropriate varieties. Also see: Factsheet no. 2 "Farm-based organic variety trials". Yet organic systems are as diverse as nature itself, so what may be the right variety for one organic farm, may be unsuitable on the neighbouring farm. Furthermore, the natural environment is becoming increasingly unpredictable due to climate change. With increasing frequency of extreme weather events, adaptation to just one environment seems increasingly inappropriate. So, what can be done?

THE CONCEPT OF EVOLUTIONARY BREEDING

A potential solution could be to grow plant populations composed of a huge diversity of plants, i.e., the opposite of a uniform variety and allow them change over time via a method known as 'evolutionary breeding'[1]. Seed from one generation is saved, bulked together rather than as individual lines, and sown in the next generation. It is expected that the frequency of well-adapted genotypes in the population increases over time through the process of natural selection. This may lead to better adaption of the population to the specific conditions faced by farmers at a given site.

Simultaneously, the genetic diversity with the population can buffer it against environmental fluctuations, as one individual may compensate the failure of another. The concept of evolutionary plant breeding was already developed in the first half of the 20th century[2] but was largely ignored by mainstream breeding. In 2001, Martin Wolfe and team joined up with breeders from the John Innes Centre to create a first set of population from a set of 20 parent varieties. These composite cross populations (CCPs) became widely known as the QCCP for high baking quality, the YCCP for high yield and the YQCCP for both purposes. At the time, trading such heterogeneous material was illegal under European legislation due to the necessity of complying with DUS rules.

Figure 2 Resilience: a lush YQCCP crop surrounds a failed crop of a commercial variety, in a field sown in suboptimal conditions

EXTENSIVE TESTING

From autumn 2004, ORC led the testing of the populations, along with some mixtures, against their respective sets of parents at two organic and two conventional sites[3]. CCPs out yielded the mean of the parents by 2.4 % and their stability was higher than that of the individual monocultures[3]. Subsequently, the CCPs were tested on several organic farms against different commercial varieties across the UK (Wheat Breeding LINK project, 2008-2013), mixed with pure line varieties and grown in different European countries (SOLIBAM project, 2010-2014) and even cycled across Europe to test their large-scale adaptability (COBRA project, 2013-2016).

Further work explored the mechanisms of evolution, comparing the CCPs to their original seed in several UK locations. After being grown as CCPs for several generations, no genetic signs of adaptation to any of the four different growing sites could be detected. However, across all locations, evidence of evolution was found as dwarfing genes had been lost from the population, probably due to stronger competition of tall plants within the population[4]. The extent of adaptation within the populations versus the role of plasticity is still an open question.

Across the various projects, several farmers, bakers, and breeders and researchers got involved in the work and became interested in the CCP concept. However, according to EU seed legislation, only seed of genetically homogeneous varieties can be legally marketed. Evidence of the potential benefits of CCPs from our research has led the EU to allow, with the directive 150/2014/EU, marketing on an experimental basis of CCPs of wheat, barley, oats and maize. Hence, the YQCCP could finally be marketed as "ORC Wakelyns Population".

The new Organic Regulation EU/848/2018, which will come into force in 2022, has introduced the concept of 'Organic Heterogeneous Material', which will make production and marketing of organic seed of populations fully legal for every crop species[5].

Conclusion

The legal recognition of genetically diverse seeds in organic agriculture means that organic farmers will be able to access seeds that they can adapt to their growing conditions, limiting the need for external inputs. This is a success story highlighting how scientific research can trigger changes in the international landscape, from legislation to farmers' fields.

Figure 3 Seed to bread: YQCCP wholegrain sourdough loaves produced by the Small Food Bakery Nottingham, UK

References

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