Plant health right from the start

Seeds represent the beginning of plant development, and seed quality and variety selection play central roles in plant health. In this article, originally published in the German magazine Ökologie&Landbau (3/2024)*, several professionals engaged in organic plant breeding discuss seed and plant health on the example of cereal and vegetable crops and current projects.*

Healthy seed with a high germination rate and vigour enable a favourable development of the seedlings, which is particularly important under organic growing conditions. Preventive agronomic and horticultural measures, such as balanced crop rotations, careful soil cultivation and adequate fertilisation, form the basis for seed and plant health in organic farming. A holistic approach also involves optimal seed production and processing as well as a high level of (bio-)diversity. In specific or acute cases, additional measures are necessary in the domains of organic resistance breeding and seed treatments. The role of the microbiota, i.e. bacteria, fungi and other living organisms, for the health and development of seeds and plants has received growing attention in recent years (see Figure 1).

Seed-transmitted cereal diseases

In the case of cereal diseases such as common bunt of **wheat** (*Tilletia* spp.) or loose smut of **barley** and **oats** (*Ustilago* spp.), even low levels of disease incidence may lead to crop failures and the rejection of seed lots in the official seed certification system. The synthetic chemical seed treatments of conventional agriculture manage to completely control these seed-borne diseases. As a result, these diseases have received little attention in conventional plant breeding during the past decades and most varieties currently available on the market are highly susceptible. In the case of common bunt of wheat, effective disease management in organic farming relies on sufficiently broad crop rotations, rigorous seed analyses, as well as targeted seed treatments in situations of high disease risk. For instance, Vinegar or plant strengtheners based on mustard powder can be used as effective agents for organic seed treatments. However, when soils are infected or the disease has already occurred on a farm, resistant varieties are also required to continue growing wheat and other bunt-susceptible cereals. This is why organic resistance breeding programmes were set up in Germany from the 1990s onwards. As a result, varieties of **wheat**, **oats**, **barley** and **einkorn** with resistance to common bunt or loose smut have already been registered (see www.biosaat.eu). This represents a major success for organic plant breeding. However, the resistances in these varieties depend on one or few genes and are constantly at risk of being overcome by the bunt or smut fungi. In collaboration with partners from all over Europe, the EIP project "Seed Health Hessen"[1] in Germany addresses this issue by investigating the spread and dynamics of common bunt races and developing of a concept for the sustainable management of resistance genes (Bender et al., 2024).

Leaf diseases in cereals

In contrast to seed-transmitted diseases, moderate levels of infestation can be tolerated in the case of leaf diseases of cereal crops such as yellow rust, brown rust, *Septoria tritici* or tan spot, especially if they occur at later stages in plant development. Major crop losses can usually be avoided by selecting adapted varieties for cultivation. In fact, high levels of resistance to leaf diseases are a priority both in

[1] t1p.de/eip-saat-gesund (consulted 06.08.2025)

organic and conventional plant breeding programmes. In Germany, for instance, several varieties approved by the Federal Plant Variety Office (*Bundessortenamt*) with organic VCU (value for cultivation and use) testing are classified as excellent in this respect. Experience shows, however, that complete resistance should not be aimed for, as it can be quickly overcome by dynamically evolving fungal pathogens. The development of variety mixtures or heterogeneous populations - allowed to be marketed as "organic heterogeneous material" in the European Union since 2022 - are promising approaches for successful resistance management strategies. Barrier and spacing effects caused by plants with different resistance levels prevent the epidemic spread of leaf diseases in heterogeneous crop stands.

Benefits from biodiversity can be gained in a targeted manner by the use of heterogeneous populations, mixed cropping with grain legumes or niche crops to enrich crop rotations. This results in interesting new perspectives to improve seed and plant health. Research institutions and organic breeding initiatives are currently investigating and working on soil- and seed-borne diseases and pests in grain legumes (such as the pea seed weevil) and plant health in **einkorn**, **emmer**, **spelt**, **naked oats** and **naked barley**.

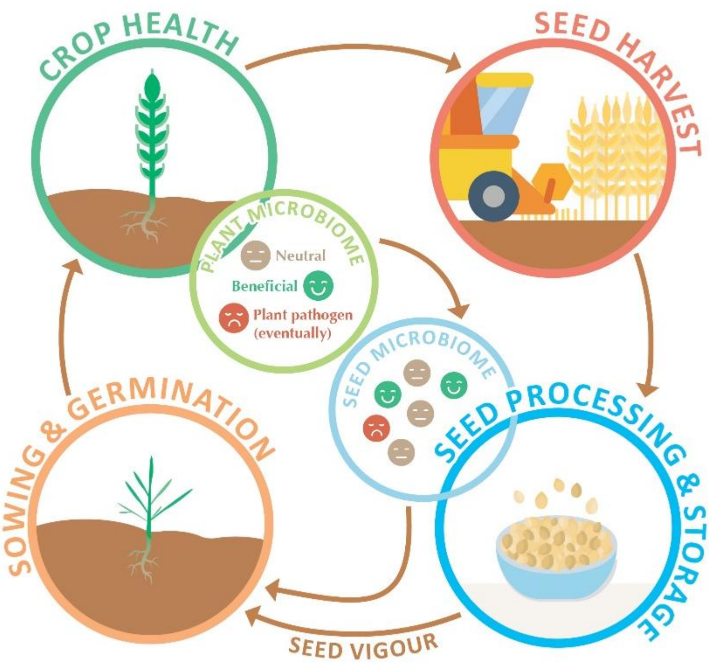

Figure 1: Factors that come into play in a holistic perspective on seed and plant health (published in Klaedtke et al., 2022)

Organic vegetable breeding

While conventional vegetable breeding uses cost- and technology-intensive laboratory methods to constantly achieve new, fully resistant varieties, the turnover of varieties in organic vegetable breeding is slower. The simple pyramidisation of resistance genes, which are usually overcome by pathogens after a few years of cultivation in highly specialised monoculture systems and that must be continually replaced by new resistances in new varieties, is neither possible nor desirable in organic vegetable breeding. Instead, varieties are developed for cropping systems that are characterised by a high level of resilience and diversity, and resistance is only considered as one measure of a of a holistic approach.

The aim is to develop well-balanced and vigorous varieties that deliver reliable yields in various target environments. Specifically for different vegetable species, the breeders of the association *Kultursaat* and of *Bingenheimer Saatgut AG* pursue this overarching goal.

Crop-specific breeding approaches

Based on the approach known from cereals, there are promising attempts to breed heterogeneous populations with buffering capacity against biotic and abiotic stresses in vegetables, as well. This innovative breeding approach is mainly suitable for vegetable crops where visual heterogeneity does not represent an obstacle for marketing the produce, as in the case of **spinach** or **lettuce** (Gärber *et al.*, 2023). Leaf mold caused by the fungus *Fulvia fulva* is a very problematic leaf disease in organic **tomato** cultivation. In the AlResiTom[2] project, Kultursaat e. V. and the Julius Kühn Institute (JKI) are working on crossing previously unused resistances to *F. fulva* into common commercial varieties and breeding lines. In this project, resistance tests are carried out in the classical way, using standardised inoculations with *F. fulva* isolates. When growing **cucumbers** in greenhouse soil, often only grafted plants can cope with the pathogen pressure that builds up over time. Until now, only conventionally bred F1 hybrids are commercially available as rootstocks. Bingenheimer Saatgut AG, in co-operation with the University of Kassel and the JKI, is currently testing an approach in which seedlings are selected in inoculated growing substrate. Presence of the necessary resistance to fungal pathogens and nematodes is tested through phenotypic selection, with the aim of making available organic seeds of open pollinated cucumber rootstocks in future.

In the case of **garlic**, which is almost exclusively propagated vegetatively, the aim is to identify varieties and origins that don't lose vigour despite virus infection. A joint project with the JKI and the organic association Bioland[3] has shown that there is no causal relationship between virus load and vigour. Several such vigorous varieties are maintained in the Kultursaat network and are available for future propagation.

Hot water treatments of vegetable seeds

While in cereals harvested grain is also used as seed, seed propagation for vegetables is often more complicated and time consuming. Many vegetable crops only go through their shooting, flowering and seed setting phases after they are ready for the vegetable market, and sometimes only in the subsequent year. If infection with seed-transmitted pathogens occurs during the generative phase, hot water treatment is a very effective and well-proven seed treatment option. At Bingenheimer Saatgut AG, it is applied for vegetable crops as necessary and enables very reliable management of seed-borne fungal and bacterial pathogens. All seed batches of cabbage, carrot, beetroot, onion, miner's lettuce, corn salad, parsley and celery are tested for such pathogens as a standard procedure.

Outlook

There are many gaps in our knowledge on seed and plant microbiota. Biological relationships and functions that contribute to the growth and protection of seedlings and to overall plant health are still largely unexplored. The fact that seed microbiota are partly passed on vertically from one plant generation to the next raises interesting questions (Berg, 2019), for example regarding the evaluation of biological seed treatment methods. Park *et al.* (2023) have shown that bean populations selected under organic farming conditions have more plant growth-promoting bacteria in their rhizosphere microbiota than those selected under conventional conditions. In an organic tomato breeding project

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[2] https://orgprints.org/id/eprint/52766/ (consulted 06.08.2025)
[3] See t1p.de/kultursaat (consulted 06.08.2025)

in the USA[4], varieties are being developed whose defences are induced particularly well under the influence of certain bacteria. All this opens promising new perspectives for organic crop breeding and seed propagation.

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[4] Tomato Organic Management and Improvement Project (TOMI), see eorganic.info/node/12999 (consulted 06.08.2025)