The wheat makers

Wheat is a staple food for the majority of our world's population. While demand for this cereal is growing rapidly, extreme weather volatility and climate change present new threats to global harvests. To meet the need for consistent, higher yielding varieties, researchers at Bayer CropScience are working with a global network of breeding stations, research facilities and partner companies to develop wheat cultivars which are fit for the future.

Choosing the greatest potential: laboratory technician Claire Pons de Vincent selects the most promising wheat plants. She and her colleagues at Bayer's wheat research center in Milly-la-Fôret near Paris are developing more effective breeding methods for the cereal.

Global cereal: wheat is grown on around 220 million hectares worldwide and is consumed in 90 countries. However, demand could outstrip the supply in the future. Bayer's scientists are therefore using new technologies to specifically increase yields.

Wheat feeds the world; more than two billion people rely on it as a traditional cereal and staple food. Its nutritious golden grains are used to make bread, pasta, beer, pizza and animal feed. Wheat is grown on roughly 220 million hectares worldwide – significantly more than other small grain cereals such as rye, oats and barley. Wheat yields per hectare have more than doubled since the late 1960s. Yet they have barely risen at all in some key regions during the last decade – a development that could have dramatic consequences. "If things stay as they are, we will struggle to meet the demand of the growing global population," says Steve Patterson, Global Crop Manager Cereals at Bayer CropScience. Even in traditional rice-growing countries such as China and Korea, wheat is becoming increasingly popular. On top of this, current yield levels may decline, mainly as a result of climate change. Patterson continues, "Extreme weather events such as prolonged periods of drought or heavy rainfall could cause wheat supply market shocks, and it is estimated that for every degree Celsius that global temperatures rise, wheat yields could decline by 6 percent." In addition, diseases and grass weeds that have become resistant to conventional crop protection agents are increasingly causing harvest losses in key growing regions.

Specialists aim to breed more robust plants for higher yields

"To secure the future of wheat, it is vital that we rapidly implement global measures which bring together wide-ranging areas of expertise and integrate them in new farming concepts," says Patterson. To this end, Bayer has built up a global network of in-house breeding stations and external partners in just a few years. The company is also cooperating with the international Wheat Initiative, which was endorsed by the G20 Agricultural Ministers in Paris in 2011. "Our goal is to breed plants which provide higher yields under the respective local climate and soil conditions and are better able to withstand extreme weather, pests and diseases," explains Edward Souza, Head of Wheat Breeding Research at Bayer CropScience. Scientists are working intensively to develop new cultivars of this staple cereal at a total of seven plant breeding stations: in Canada, Germany, France, Ukraine, Australia and two stations in the United States. This global breeding program in-

"Wheat yields will have to increase dramatically to meet demand."

Steve Patterson, Global Crop Manager Cereals at Bayer CropScience

Photos: Peter Ginter/Bayer AG (3), Sabine Bungert/Bayer AG (1), Dirk Hansen/Bayer AG (1), Ludovic Combe/Horizon Photographie (1)

The history of wheat

The oldest evidence of wheat dates back around 10,000 years, making wheat the second oldest cereal after barley. The wild ancestors of modern wheat, like most grasses, had very slender seed heads, which shattered easily and scattered the seeds on the ground. This made them difficult to harvest, so early farmers selected specimens with particularly thick seed heads and used them to breed varieties with ears which remained intact until they were threshed.

The first cultivated species were einkorn and emmer. Initially grown in the Middle East, these varieties were robust, capable of growing even in inhospitable places and stored well. Despite its many advantages, however, wheat was long regarded as a niche product. It was not until the 11th century that the grain became popular. In the 1950s researchers made an important breakthrough: they discovered a dwarfing gene in wild grasses which they crossed with domestic wheat. The new plants were smaller and more stable, and could carry more grains. This knowledge was used as part of the green revolution that led to a doubling of yields in many countries, including India. Today around 5,000 different varieties of wheat are grown around the world.

Common wheat covers 90 percent of the area devoted to wheat growing, and is the principal component of bread and animal feed. It is also used to produce starch. This wheat species was the result of a spontaneous crossing between emmer wheat, the ancestor of durum wheat, and a wild goat grass. Durum wheat has a particularly high gluten content and is used mainly for pasta and noodles, as well as bulgur and couscous. Needing little water and being well-suited to hot climates, it is grown predominantly in the Mediterranean region and the Middle East.

volves over 400,000 test plots and 8,000 different elite experimental varieties.

The scientists are pursuing several different strategies, including the breeding of more robust and high-yielding hybrids. "These are produced when two pure lines selected for quite specific traits are crossed with one another," Souza explains. First-generation (F1) hybrid seed is particularly desirable because it produces significantly higher yields than the parent varieties. To produce such hybrids, breeders have to suppress pollen formation in one parent line by making it sterile. "If this doesn't happen, the plants self-pollinate and the yield-boosting effect is lost," says Souza. The few programs making F1 varieties of wheat today use chemical sterilants, which are however only approved for use in a few countries. Bayer researchers in Souza's team have turned their attention to genetic sterilization to solve this problem, using native genes from wheat and closely related species.

Using information from the wheat genome sequence, Dr. Catherine Feuillet and her team are working on discovering and improving the genes underlying yields to accelerate the selection and creation of improved varieties.

Scientists are working with some 8,000 wheat varieties

"We also use more conventional breeding processes to combine the desired traits – for instance, crossing particularly resistant wild wheat with modern, high-yielding varieties," Patterson explains. The experts at Bayer are using new technologies which greatly accelerate the breeding process. "Using molecular markers, we can quickly identify suitable candidates for cross-breeding and discard less suitable variants at an early stage in the process," explains Souza. Prior to this, the selection relied solely on the trained eye of the breeder, who had to assess the value of a new variety based on plant growth, leaves and root development.

"We are particularly interested in identifying the genes responsible for yield and resistance to biotic and abiotic stresses," says Dr. Catherine Feuillet, a wheat geneticist who leads the Trait Research department at Bayer CropScience. Over the past ten years, she has devoted herself to a particularly daunting task: deciphering the wheat genome. With 17 billion base pairs, however, the wheat genome is five times larger than the human genome, and far more complex. Each plant cell contains three sets of chromosomes that contain multiple copies of the same information. "Decoding the wheat genome was long thought to be technically impossible or simply too expensive," says Feuillet. However, progress has now been made, thanks largely to the International Wheat Genome Sequencing Consortium (IWGSC), an organization in which Feuillet holds a leading position and which also receives financial support from Bayer CropScience. "We have already succeeded in obtaining a reference sequence from the largest chromosome and have produced rough drafts of the other 20," she says. These are useful to develop markers that can be used by Souza's team as well as breeders around the world, but complete sequence information is still

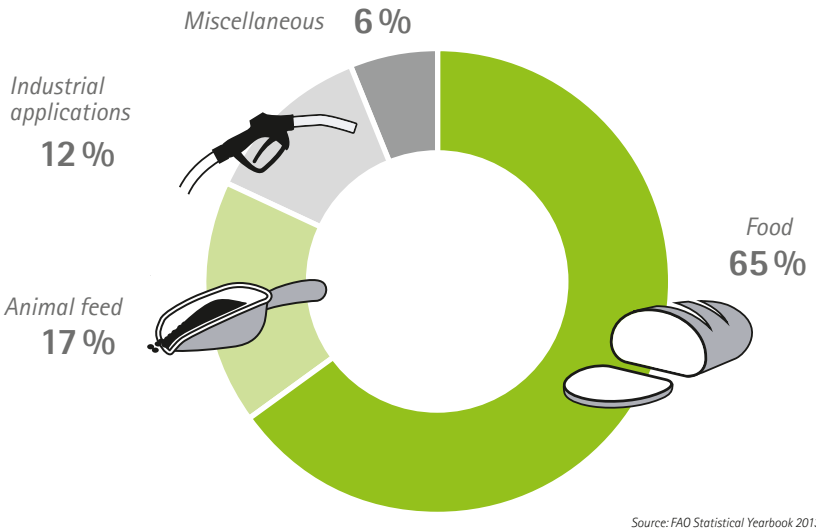
Precision work: sterile tweezers are used to remove stamens from a wheat ear (photo left) to ensure that the plant cannot self-pollinate and can thus be selectively cross-bred. In the greenhouse, Céline Zimmerli and Guillaume Plé (photo right, left to right) test how the developed varieties behave under different light, temperature and nutrient conditions.

needed to identify and isolate the genes underlying the desired traits.

"Knowing which genes are responsible for yield will enable us to optimize gene combinations through breeding, discover even better versions as well as engineer some genes to increase the efficiency of those pathways leading to higher yields," explains Feuillet. All approaches that lead to greater diversity in wheat cultivars are therefore part of the wheat tool box that Bayer CropScience is currently developing. For this reason, experts at Bayer are collaborating with a variety of external partners, including biotech companies such as KeyGene in the Netherlands, the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the National Agricultural Research and Development Institute in Romania. The University of Nebraska, South Dakota State University and Texas A&M University, which have expertise in drought-resistant varieties, and Kansas State University, a world-renowned center for characterizing and using wild wheat varieties, are also on board.

How wheat is used

Wheat is not just used to make bread and pasta. The cereal is also used in the manufacture of industrial products such as biofuel and in animal feed for livestock and companion animals.



Source: FAO Statistical Yearbook 2013

International network for an effective wheat strategy

But the future of this golden grain cannot be ensured purely by developing premium wheat varieties. New, more effective crop protection products are also part of Bayer's strategy, as is working together closely with farmers. "Even today, producers can achieve significantly higher yields by making full use of every opportunity for good agricultural practice, from crop rotation to optimum use of fertilizers and crop protection products," says Patterson. Digital technology is also increasingly being used to develop tailored regional solutions. For instance, sensors and cameras mounted on farm machinery provide valuable data about the soil, moisture content, plant growth and yields. "With new varieties, effective crop protection products and optimal management strategies, wheat yields could again significantly increase to meet the needs of the growing population," estimates Patterson. This would effectively amount to a revolution in wheat and make a vital contribution to global food security.

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