

HELPING THE WORLD TAME WILD WHEAT

A global wheat breeding research project with Australian participation could potentially increase wheat yields and help meet increasing population-driven demand. Brendon Cant reports

Groundbreaking research, using breeding strategies that complement conventional wheat breeding, has shown yield can be lifted by selecting certain physiological traits. Such increases, needed to satisfy an expected surge in demand over the next 25 years, cannot be obtained through conventional breeding. Wheat breeder Dr Matthew Reynolds, who headed an ACIAR-funded research project at the International Maize and Wheat Improvement Center (CIMMYT) in Mexico, says today's wheat appears to retain characteristics from its wild wheat ancestors, therefore leaving room for improvement.

"We are still taming wheat," he says. "Wild wheats used to grow in competition with other plants such as weeds, whereas today farmed wheats largely compete with themselves."

CSIRO Plant Industry, the Australian National University and the University of Queensland worked together on the project, which ran from 1999 to 2006.

Dr Reynolds says new breeding techniques are crucial to meet the expected increased demand. "Current rate of genetic progress from breeding will not meet predicted demand, especially in the developing world," he says.

Wheat is a staple food with 220 million hectares grown worldwide – half of it in developing countries. CIMMYT believes that worldwide demand for wheat will grow by about 1.3 per cent – and slightly more than this figure in developing countries.

Wheat breeding programs around the world, particularly during

the 'Green Revolution' in the 1960s, made significant genetic gains in yield potential without the aid of physiological selection tools. But improvement in genetic yield potential since then has fallen to less than one per cent a year, too low to keep pace with future demand.

Dr Reynolds, who recently published a review on impacts of international wheat breeding with wheat breeder and Nobel Laureate Dr Norman Borlaug at CIMMYT*, says the Green Revolution, which helped feed the world, also reduced pressure on the environment.

CIMMYT research indicates that if the global cereal yields of 1950 had still existed in 1999, an extra 1.8 billion hectares of similar land would have been required. But the extra land would not have been available without deforestation and exploitation of marginal lands, least of all in Asia, where the population increased from 1.2 to 3.8 billion in that period.

Also, if natural ecosystems had been brought into agricultural production at the time, the environmental consequences would have been the loss of biodiversity, and the extinction of some plant and animal species. There was also the issue of unforeseen disease epidemics that could wipe out many of the world's crops, leaving a critical shortage of a staple food unless a way was found to improve resistance to disease.

For example, a major stem rust epidemic could cut world wheat production by at least 10 per cent within one or two years, cause huge economic loss and reduce the calorie intake of millions of people.

The research – 'Increasing yield potential in wheat: complementing conventional breeding by application of novel physiological and



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germplasm strategies' – was conducted in Mexico and Australia.

Dr Reynolds says identification of traits that limit yield through experimenting in field environments, or searching for better sources of those yield-limiting traits in genetic resource collections, could help lift yield. Traits could also be combined into good background cultivars and selected for increased yield, using integrative physiological traits such as canopy temperature.

To find these traits, researchers have been turning to wild wheats and ancestral grasses that contain the genetic origins of modern cultivated plants.

The team found that stomatal-aperture traits, such as leaf permeability and canopy temperature depression were useful for indirect selection for yield potential as well as yield under drought. Incorporating these traits into breeding and selection should increase progress by dollar spent.

The team also found spike fertility and biomass at flowering limited yield. "We have found germplasm with greater spike fertility and developed screening techniques, such as spectral reflectance, to screen for biomass at flowering," Dr Reynolds says. "Collaborations in the UK have also been established to determine the genetic basis of spike fertility in spring and winter crosses with large spike materials."

Dr Reynolds says a piece of chromosome associated with leaf rust, containing gene LR19, has been shown to be associated with increased spike fertility in wheat, but in this case only delivered higher yield under optimal conditions. Results from the trials could be followed

Wild ancestors, and also the seed of old landrace varieties that have self-sown in remote areas, have become an importance genetic resource as researchers seek out traits that will give modern wheat crops more environmental resilience.

Dr Matthew Reynolds

up in several ways, he says. Molecular markers could be developed for stomatal aperture-related traits and other yield-enhancing traits to provide additional tools for improving breeding efficiency.

The true biological yield potential of wheat in different environments, including marginal environments, based on physiological insights gained from the current work, could also be further exploited. And the capacity of national agricultural research systems (NARS) to fully implement the use of physiological selection criteria in breeding could be developed.

While one of the aims of the research was to help poorer countries gain greater yields for themselves and therefore not have to import expensive grain, there were also benefits to Australian wheat growers.

Dr Reynolds says the technologies being developed are equally applicable to collaborating countries and NARS breeding programs. Increasing yield potential in a high-yielding wheat is also good for wheats in low-yielding environments, and he says higher-yielding wheats in irrigated environments could be adapted to drier areas such as Australia.

The varieties with higher genetic yield potential, when combined with genetic disease resistance, were generally higher yielding under all levels of inputs, so farmers benefited, irrespective of how much fertiliser was used.

The technologies developed by the ACIAR project should also significantly improve the efficiency of early generation and advanced line selection. They should also provide a better knowledge base to develop more strategic crossing plans, by identifying yield-enhancing traits in new and conventional sources of germplasm.

Dr Reynolds' report states that shifting the wheat yield frontier will have an immediate impact on raising farm level yields and reducing unit production costs. This should mean greater domestic food security and more wheat available at a lower price, therefore benefiting poor consumers, rural and urban.

The report says if the research could improve the rate of increase in genetic yield gains by just one tenth, or from 1.0 per cent to 1.1 per cent a year, the annual output will reach 685 million tonnes a year by 2020.

The international wheat breeding research funded by ACIAR through international agricultural research centres (IARCs) such as CIMMYT means research is not duplicated and poor countries do not need to spend money developing their own technologies. IARCs provide continuity in agricultural development that would otherwise be uncertain for many less developed countries where economic, political, and social instability are commonplace.

While national wheat breeding programs in countries such as Argentina, India and China are stable, there is a high turnover of researchers and some may not even get regular funding.

The benefits and efficiency of the international collaborative platform are indisputable when considering the duplication otherwise needed to achieve the same impacts through unilateral or even bilateral programs.

One of the major challenges to improving food security in rural resource-poor communities is to develop cultivars tailored to specific local environments. While germplasm can be developed at a national and international level to incorporate generically useful traits, it is a major challenge for scientists with limited public sector resources to test the full range of genetic diversity generated by a breeding program under all possible environments.



* See 'Big bang from wheat breeding bucks', www.cimmyt.org