With the assistance of a GRDC travel grant, DAFWA senior research officer Chengdao Li, travelled to Austria in August this year to attend and present a paper at the International Symposium on Induced Plant Mutation. The symposium marked 80 years since mutation technology began to be used as an important tool in plant science and crop improvement.

USING MUTATION TECHNOLOGY TO IMPROVE CROPS

By Chengdao Li, Department of Agriculture & Food WA

Soil acidity with high levels of toxic aluminium is the largest (in area) soil constraint limiting sustainable crop production in Australia. For example, about two thirds of the Western Australian wheatbelt soils are either acid or at risk from soil acidification. Soil acidity impairs root growth of sensitive crops and hence reduced nutrient acquisition and plant access to water reserves in the deep layers, especially in the low-rainfall regions where the topsoil often dries out in late growing stages.

Surface liming is a common practice to ameliorate topsoil acidity but is insufficient to decrease acidity below the plough layer because of slow movement of lime in soil profiles. Current barley cultivars are generally sensitive to soil acidity as compared to bread wheat and other cereals.

A field study at Wongan Hills, WA, showed that yields of Mundah barley were decreased at soil pH below 5. The yields decreased by 40 per cent where the topsoil pH was 4.7 and 4.1 in the 10–30 cm layer Wheat yield is generally decreased by soil pH below 4.5 where toxic aluminium becomes active. Genetic improvement of varieties with tolerance of acidic soils is the best solution.

WHAT IS INDUCED PLANT MUTATION?

Mutation breeding refers to a technique used to create heritable changes (mutations) in crops to introduce the desirable genes and therefore the trait into the crop. Mutation may occur naturally but most are induced through the use of various forms of energy such as neutrons, gamma rays and X-rays or various chemical treatments. Recently, cosmic ray radiations are also being explored to create novel mutations through recoverable satellites.

Over the past 80 years, plant geneticists and breeders have created numerous mutants through physical radiation, chemical mutagenic agents and transposable elements.

Induced mutagenesis in plants has been established as the tool of choice for creating novel alleles of genes for use in crop improvement programs. Such alleles are usually absent, or otherwise hard to exploit, from crop germplasm available to plant breeders.

Screening germplasm with acid soil tolerance

Over 200 barley lines were introduced from around the world and tested on acid soils in Wongan Hills and Merredin. A glasshouse screening method for acid soil tolerance has been established. The average root length under low pH and high aluminium can be used as the best indicator for acid soil tolerance.

The best tolerant lines include Svanhals from CYMMIT, Br2 from Brazil, Dayton and WB229 from Australia. Six lines were promoted to special stage 4 trials on acid soils in Carrabin South and Kalannie. These lines out-yielded the current variety Stirling by an average of 30.8 per cent. The best two lines WB223 and WB229 out-yielded Stirling by 45 and 42 per cent respectively.

Mapping the gene for acid soil tolerance

Four barley doubled haploid populations were developed for mapping the acid soil tolerance genes from Svanhals, Br2, Dayton and WB229. One major gene for acid soil/aluminium toxic tolerance was mapped on chromosome 4H. A candidate gene HvMATE is believed to control acid soil/aluminium tolerance at this locus [1]. The expression level of this gene was associated with acid soil tolerance.

Dr Li Chengdao Li (second from left), Dr Qinyao Shu from the International Atomic Energy Agency and Dr Justyna Guzy-Wrobelska from Poland discuss mutation breeding.

Development barley variety with acid soil tolerance

The WA barley breeding program is endeavouring to accelerate development of acid soil tolerance malting barley varieties through molecular genetic marker and doubled-haploid techniques.

High throughput molecular marker techniques were developed. Acid soil tolerant genes were transferred into the current malting barley varieties Baudin and Hamelin using MAS. It shortened the breeding cycle by two years.

The new breeding lines showed over 30 per cent yield advantage on acid soils. In 2007, the most advanced lines were tested in 25 sites around Australia with various soil types. The new breeding lines showed 20 per cent yield advantage over control.

Search new tolerant genes through mutation

Although the new breeding lines showed significant yield advantage, these tolerant barley lines are still more sensitive to soil acidity than tolerant wheat. Only one acid soil tolerance gene was identified in the Australian barley germplasm. The resistance mechanism (citrate secretion) seems different from wheat (malate secretion).

Transformation experiments confirmed that the malate secretion mechanism provides excellent tolerance in barley. Two barley varieties, Dash and Vlamingh, were treated with gamma-rays or exposed to cosmic rays. New mutants were screened for acid soil tolerance.

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HIGH HOPES

"At a time when the world is facing a food and energy crisis of unprecedented proportions, plant mutation breeding can be a catalyst in developing improved, higher-yield, saline-resistant, sturdier crop varieties," Werner Burkart, Deputy Director General of the International Atomic Energy Agency (IAEA), told The International Symposium on Induced Mutations in Plants.

Werner said 2008 will be remembered as the year in which the world understood the realities of climate change, the food crisis and the energy debate in its link to hunger.

"These big issues are intimately interlinked, and translate in the agronomy field into a competition between food, feed and fuel for soil, water, human and financial resources," he noted.

Mutant barley in Peru

One success story is mutant barley varieties that thrive at altitudes of up to 5000 metres in the highlands of Peru and which led to a 52 per cent increase in yields between 1978 and 2002.

"The breeding of new mutant varieties – with a higher yield potential, more productive biomass for energy use, better nutrient composition for human health, better adaptation to climate change and variability, or a heightened potential to sequester carbon – will be the driving force to meet the challenges of the 21st century," he stated.

SYMPOSIUM HIGHLIGHTS

Low phytic acid crops

Phytate is a compound found in most cereals and grain legumes. It accounts for about 70 per cent of phosphate in barley and wheat grains and is not digestible by humans and mono-gastric animals. Phytate acid 'ties up' or sequesters divalent cations. In humans and other mono-gastric animals, such as pigs and chickens, the presence of large amounts of phytate in the diet can be related to two significant issues.

- It can significantly compromise the uptake of divalent nutrients resulting in mineral nutrient deficiencies. Small scale human and animal experiments have shown 50 per cent higher iron (Fe) and 76 per cent higher zinc (Zn) efficiency of low phytic acid maize. It is a significant issue for pregnant and lactating women and for growing pigs and chickens.
- When young pigs and chickens are fed diets high in phytate, a significant amount of phosphate will be unavailable and will be excreted in the faeces. This has consequences for intensive animal husbandry and effluent management.

In short, high phytate in grains can result in malnutrition in humans and animals, low efficiency of P fertilisers and environmental pollution.

Development of crops with low phytate is becoming a global strategy to combat these issues. New varieties with low phytate have been developed in rice, maize, barley and soybean, and commercialised in the US, Europe, Canada, Japan and China.

DAFWA has participated in the international working group on low phytic acid crops and a new project proposal has been submitted to the GRDC for developing Australian low phytic barley and wheat.

Reverse genetics and high throughput techniques for mutation screening

A number of new gene discovery technologies were discussed. These techniques not only create novel genetic materials for breeding they also help our understanding of gene function and how to tag the novel alleles in the breeding programs.

Several techniques have been developed as reverse-genetic tools for the screening of a large number of plants having radiation or chemical induced mutations.

During the symposium Chengdao had talks with various member countries to discuss the possibility of allowing Australian researchers to access their nuclear facilities, including gamma rays, fast neutrons, laser, x-rays, ion beams, thermal neutrons and gamma chronic field.

The space breeding workshop will facilitate Australia to participate in mutation breeding research in the Ground Cosmic Simulation Centre in China.