Feeding the future

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(PhysOrg.com) -- At the current growth rate the global population is predicted to reach 10 billion by 2050. To feed this many people, food production worldwide will need to double during a period when climate change will worsen, fossil fuels will dwindle, and water availability will become unpredictable.

In addition, if we are to protect what biodiversity we can, this doubling of agricultural output must take place using the same amount of farmland, without impacting upon remaining natural habitats.

To tackle this problem, scientists in Oxford University's Department of Plant Sciences are aiming to develop high-yield crop strains which will be better adapted to this climate-altered, resource-poor agricultural landscape of the near future.

Boosting rice crops

Professor Jane Langdale, Head of the Department of Plant Sciences, is engaged in the 'C4 Rice' project, an international effort funded by the Bill & Melinda Gates Foundation. 700 million people in Asia currently depend on rice for the bulk of their calorific intake and it is predicted that during the next 40 years, rice production needs to increase by 50 per cent in order to feed the growing Asian population, whilst adapting to adverse changes in climate and water availability.

Photosynthesis converts carbon dioxide and the energy from sunlight into chemical energy and takes place in cell organelles called chloroplasts. The chemical energy produced in these chloroplasts is then used by plants to live, grow, and in the case of crops, produce grain.

Conventional rice varieties use a standard photosynthesis pathway known as 'C3', but under certain conditions, such as warmer temperatures, this pathway is inefficient. A number of plants, including maize, have evolved an extra photosynthesis pathway, called 'C4', to solve this problem. The C4 photosynthesis pathway can increase efficiency by 50 per cent and iintroducing it into rice could provide the answer to Asia's impending food problem.

The C4 Rice project is often quoted as being 'highly ambitious'. In order to work, large changes need to be made to both the anatomy of rice leaves and the chemical reactions that take place inside them. However, there is encouraging evidence that it could be done.

Jane's work on the GLK genes suggests that they may play a role in regulating whether a plant's chloroplasts use C3 or C4 photosynthesis. Ongoing work in her laboratory seeks to put GLK genes from maize, a naturally C4 crop, into rice plants. Her work on chloroplasts began due to an interest in the genetic control of development in plants, rather than a specific aim to put C4 photosynthesis into other plant species. Whilst developing new C4 crops had always seemed like an interesting idea, she never thought it would be realistic.

20 years of chloroplast research later, Jane was ready to move into new research areas. It was at this point, in 2006, that the International Rice Research Institute (IRRI) invited Jane to a C4 Rice Consortium workshop. Originally reluctant to go, she was persuaded to attend by Julian Hibberd from the University of Cambridge, and found herself getting excited by the proposed project. She is now 5 months into a 3 year "proof of concept" project involved in testing the feasibility of C4 Rice, a necessary step called for by a paper in Current Opinions in Plant Biology written with Julian and John Sheehy from IRRI last year.

Using less fertiliser

As well as facing climate change, 21st century agriculture will also have to cope with the decline in fossil fuels. The work of Oxford's new Sherardian Professor of Botany, Liam Dolan, aims to produce crops which grow healthily without excessive phosphate-rich fertiliser application.

Phosphate is required by all living organisms to build cellular components and the low availability of phosphate in natural environments can severely limit plant growth. The soil of all of sub-Saharan Africa and one third of China is deficient in this crucial nutrient. The application of artificial fertilisers all over the world has so far dealt with this problem and contributed to the increase in productivity seen in the Green Revolution of the 20th Century.

Phosphate is extracted from mines, mainly in Morocco, the USA, China, the Former Soviet Union and South Africa, with 80 per cent of the phosphate produced being put into fertilisers. The extraction and transport of phosphate for agricultural use constitutes a considerable annual cost and carries a large carbon footprint. Furthermore, like oil, phosphate reserves are finite, and some predictions claim that phosphate mines could be exhausted within the next 30 years.

Liam's work aims to develop crops which are better adapted to scavenge their own phosphate from the soil, making them less dependent on artificial fertilisers.

Plants can naturally extract their own phosphate from the soil using root hairs, single-cell structures which grow along roots. Liam's research group have discovered a family of genes which control root hair growth and they are working to modulate the expression of these genes in crop plants. Their aim is to increase the number of root hairs a plant produces in response to naturally occurring phosphate in the soil. They have developed transgenic wheat and rice varieties capable of producing longer root hairs and are now moving on to field experiments to test the yield of these plants in the absence of commercial fertiliser.

Unlike Jane Langdale's chloroplast work, this has always been the aim for Liam. He jokes that his team are now finally at the stage he had hoped to be at by the end of his PhD, explaining that this has been a very large project, starting from scratch and requiring the discovery of all the necessary genes involved.

Planning for 21st Century

In light of the global food security crisis we will soon be facing, the University's Department of Plant Sciences will next year be launching a 21st Century Crops research initiative. This initiative seeks to found an Oxford Professorship in Crop Science and to encourage translational research, so that discoveries made about plant metabolism, growth and development can be transferred to agriculturally valuable crop plants.

However, both Jane and Liam believe that whilst plant science has a lot to offer in solving the food security challenge, the role of governments and funding bodies is crucial, a point that was emphasised at the 'Food Security in the 21st Century' Symposium hosted by the Department's graduate students last October.

Due to the unequal distribution of global wealth, the countries facing the most immediate problems do not have the funds to overcome them. Jane argues that to tackle food security there must be sustained funding and input from wealthy countries in order to bring about developing nation benefits. Liam points out that every day the same number of people die from malnutrition as from cancer, reflecting the bias of interest in developed countries. However, whilst scientific research alone cannot solve the issue of food security in the face of global politics, it is, says Jane, a very exciting time to be a plant scientist.

Provided by Oxford University