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Soaking up the sun

FOTOLIA

By 2050 we will have more than 9 billion mouths to feed. Current crop productivity will not cope. **Liz Sheffield** explains how GM might help change that

On a bright sunny day, most plants are only able to use 20% or less of the sunlight they absorb. One reason for this is that they have ways to protect themselves from damage that would be caused by excess energy. Instead of capturing all the energy, they dissipate some of it back into the environment as heat. This process is called non-photochemical quenching (NPQ) and is crucially important in preventing oxidative stress from damaging the components of the photosynthetic pathway.

The way NPQ works has been compared with the safety valve on a steam engine. When the pressure builds up to dangerously high levels, the valve opens (NPQ increases) to let out excess steam. One problem with the way NPQ works in most plants, however, is that the 'valve' takes a long time to close again once the pressure has dropped. So if clouds impede the sunlight, the plant carries on wasting some of the incident light as heat while the NPQ mechanism gradually shuts back down. Calculations show that this can cost field crops up to 20% of their potential yield. This inefficiency can be fixed, however, through genetic modification.

Researchers have access to a range of mutants of the 'model' plant, thale cress (*Arabidopsis*). This small flowering plant is the firm favourite of plant scientists for experiments because it is quick and easy to grow, reproduces within weeks of germination, and is easy to manipulate genetically. Some mutants were found with photosynthetic rates that recovered rapidly after light intensities dropped. In these mutants researchers showed that accelerated interconversion of certain pigments, called xanthophylls, and increased amounts of a subunit of photosystem II caused the NPQ mechanism to shut down more rapidly. The researchers isolated the genes responsible and incorporated them into tobacco plants.

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Tobacco is good for us

Tobacco is another model plant, and was used in this study as a 'proof of concept'. The researchers first self-pollinated the genetically manipulated (GM) plants to make homozygous lines, then tested them in the laboratory. The most promising ones were then grown in field conditions. The researchers found productivity increases of between 14 and 20%.

Figure 1 illustrates why GM plants are more productive. The plots show a measure of photosynthesis — the net fixation rate of carbon dioxide. The first few readings were taken in high light intensities, when NPQ would have been operating. The arrow shows the time at which the light hitting tobacco leaves was decreased. The green symbols represent CO_2 fixation in wild-type tobacco, the yellow symbols are from leaves of GM tobacco plants. Photosynthetic rate plummets equally fast in both sets of plants when light intensity falls. The plants incorporating the *Arabidopsis* genes, however, switch off NPQ significantly more quickly than the wild types. Now 'all' the researchers need to do is to incorporate the same genes into crop plants such as rice, wheat and other food crops.

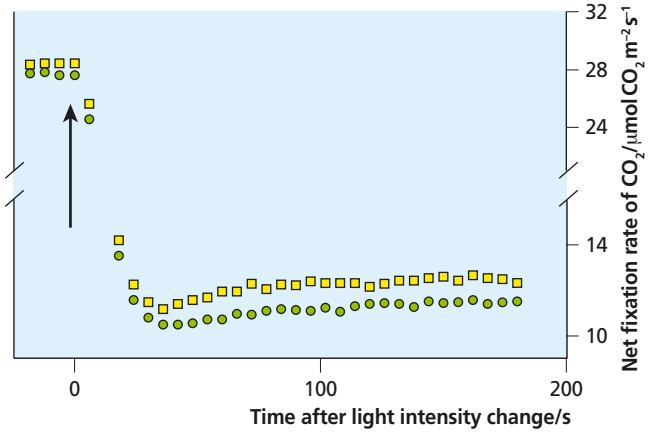

Figure 1 Net fixation rate of carbon dioxide

Activities

1 Watch the BBC news item, 17 November: **www.bbc.co.uk/news/science-environment-37988439**. The presenter suggests that it will take 20 years for this technique to generate improved crop plants. Explain why this will probably take such a long time, and discuss the challenges that might arise before the crops would be acceptable to the public.

2 The research described focused on light-use efficiency but plants have increased conduction of water through their stomata during NPQ. What might this mean for water-use efficiency in GM plants with faster rates of relaxation of NPQ, and what would that mean for future crop production?

Weblinks

For an engaging, simple account of the research see: **www.youtube.com/watch?v=Av0dTk9KzIY&feature=youtu.be**

If global warming continues, we might not need GM plants. Doubling of atmospheric carbon dioxide concentration would cause global plant photosynthesis to increase by about one third, according to some researchers. **www.sciencedaily.com/releases/2016/10/161003112208.htm**

Scientists have long been trying to improve photosynthesis. A newly discovered enzyme from the algal model plant *Chlamydomonas* could give us better crops. **www.sciencedaily.com/releases/2016/09/160920135224.htm**

Because they are easy to genetically manipulate, tobacco plants can be used as factories to produce useful compounds, e.g. high yields of a drug that combats malaria. **www.sciencedaily.com/releases/2016/10/161020142815.htm**