Dwarf Plants and the Green Revolution

The Green Revolution saw cereal crop yields triple in some areas, thanks mainly to the development of new, semi-dwarf varieties.
During the 1960s, plant breeders developed new cereal varieties with shorter stems than before. These new varieties produced better yields, as dwarf plants use more of their energy for filling the grain than in growing taller. Shorter plants are less likely to fall over, which also increases overall harvest yield, and the new varieties helped prevent starvation for many people across the world.

Although the dwarf trait can be bred into wheat by conventional methods, it has not been widely used in other cereals.
The genetic basis for the dwarf characteristic in wheat was the *Rht* gene, which has been available to plant breeders for 40 years. While it has been used extensively to develop new wheat varieties, it cannot be transferred into other cereal species that do not interbreed with wheat.

Current trends suggest that we need a second "Green Revolution" to feed the growing population on the land currently available for cultivation. Predictions suggest that by 2050, current crop yields must double in order to keep pace with the increasing world population. But with little uncultivated prime arable land remaining, yields must increase still further on land already used for food production.

The *"GAI"* gene from the non-crop plant *Arabidopsis* was found by John Innes Centre scientists to be the equivalent of the cereal *Rht* gene of the Green Revolution.
A research programme focussing on the plant hormone gibberellin led scientists at the John Innes Centre to discover a "dwarfing" gene, termed *GAI*, in Arabidopsis. This small, simple plant (also known as thale cress) is used by scientists across the world as a "model" plant to give them insights into how other, more complex crop species work. Gibberellin promotes plant growth, and the *GAI* gene determines how the plant responds to this hormone. Plants carrying an altered version of the *GAI* gene are less sensitive to giberellin, so are dwarf. Scientists soon realised that *GAI* is the Arabidopsis equivalent of the cereal Rht gene of the Green Revolution.

Using genetic modification, new dwarf varieties of cereal crops other than wheat will be possible.
Instead of the extensive recombination of genes from both parents that is characteristic of conventional plant breeding, genetic modification (GM) permits one or a few genes to be introduced with the minimum of disruption to other genes in the plant. This means that the desirable features of existing commercial cereal varieties (such as disease resistance and grain quality) can still be maintained after an additional "dwarfing" gene has been inserted.

The ability to insert the GAI gene precisely into plants offers new possibilities for improved crop performance in the field.
Now it has been isolated, the *GAI* gene will not be restricted to wheat, or even cereals. The JIC scientists have since discovered that they can also control when and where in the plant the dwarfing characteristic is active. This will give them much more flexibility in controlling plant growth to potentially improve plant performance and yield.

Other changes to plant architecture might also be possible in future that could also improve crop yields.
The discovery of the *GAI* gene has revealed that it is possible to alter plant height and dramatically increase crop yield. Other modifications are also possible, for example changing the root architecture might enable increased uptake of nutrients and water from the soil, while changing the arrangement of leaves might help the plant to make the most of the available light.

GM-assisted plant breeding could provide a key to a second Green Revolution needed to provide enough food to support the population. The first Green Revolution, despite its massive beneficial impact, is now seen as being relatively crude. It depended on plant breeding, but also required farmers to use increased amounts of fertiliser on their crops. This meant it didn't benefit many poorer farmers who didn't have access to these chemicals. Also excessive use of chemical fertilisers can have a harmful effect on the environment. This case study shows how GAI allows breeders access to useful genes not available by conventional breeding and to tailor these genes in precise ways to deliver desirable outcomes.

The potential for GM technology to improve crop yield still further is a valuable step towards the goal of a second Green Revolution with less dependence on chemical inputs.

References

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