improving the palatability.

GOLDEN RICE — THE PROVITAMIN A ENRICHED RICE

About one-third of the world's population is dependent on rice as staple food. The milled rice that is usually consumed is almost deficit in β-carotene, the provitamin A. As such, vitamin A deficiency (causing night blindness) is major nutritional disorder worldover, particularly in people subsisting on rice.

To overcome vitamin A deficiency, it was proposed to genetically manipulate rice to produce β-carotene, in the rice endosperm. The presence of ***β-carotene in the rice gives*** a characteristic ***yellow/orange colour***, hence the provitamin A-enriched rice are appropriately considered as Golden Rice.

In ***Fig. 50.13*** an outline of the biosynthetic pathway for the formation of β-carotene is given. The genetic manipulation to produce Golden Rice required the introduction of three genes encoding the enzymes phytoene synthase, carotene desaturase and lycopene β-cyclase. It took about 7 years to insert three genes for developing Golden Rice.

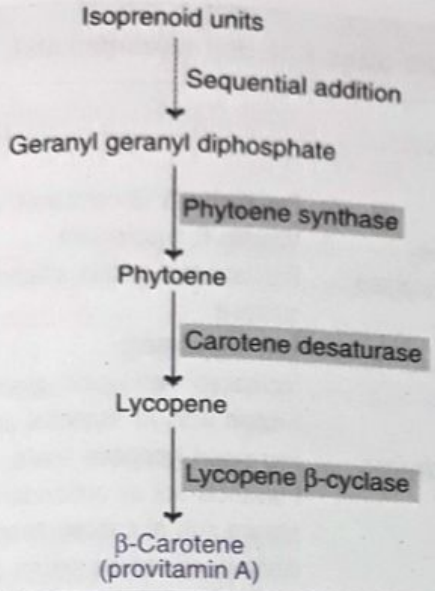

***Fig. 50.13 :** An outline of pathway for the biosynthesis of provitamin A (β-carotene).*

Golden Rice has met almost all the objections raised by the opponents of GM foods. However, many people are still against the large scale production of Golden Rice, as this will open door to the entry of many other GM foods. Another argument put forth against the consumption of Golden Rice is that it can supply only about 20% of daily requirement of vitamin A. But the proponents justify that since rice is a part of a mixed diet consumed (along with many other foods), the contribution of provitamin A through Golden Rice is quite substantial.

Recently (in 2004), a group of British scientists have developed an improved version of Golden Rice. The new strain, Golden Rice 2 contains more than 20 times the amount of provitamin A than its predecessor. It is claimed that a daily consumption of 70 g rice can meet the recommended dietary allowance for vitamin A.

TABLE 50.9 A selected list of transgenic crop plants (GM crops approved in USA) for commercial use

Crop plant	*Genetically altered trait*	*Product name*
Cotton	Insect resistance	Bollguard
	Glyphosate resistance	Roundup ready
	Bromoxynil resistance	BXN
	Sulfonylurea resistance	—
Maize	Insect resistance	Yield Guard
	Insect resistance	Maximizer
	Glyphosate resistance	Roundup Ready
	Glufosinate resistance	Liberty Link
Rice	Vitamin A enrichment	Golden Rice
Tomato	Delayed ripening	Flavr Savr
	Delayed ripening	Endless Summer
	Virus resistance	—
Soybean	Glyphosate resistance	Roundup Ready
Potato	Insect resistance	Newleaf
	Modified starch	—
Oilseed rape (canola)	Glufosinate resistance	Innovator
	Glyphosate resistance	Roundup Ready
	High lauric acid	Laurical
	Male sterility hybrid	—
Squash	Virus resistance	Freedom II
Tobacco	Virus resistance	—
Capsicum	Virus resistance	—
Carnation	Modified flower colour	—

Table 50.10 Some examples of transgenic crop plants (GM plants) at the developmental stages

Plant	*Gene transfer*	*Trait transferred/application(s)*
For improving human health		
Tomato	Phytoene desaturase	Provitamin A (β-carotene) supplement
Canola	γ-Tocopherol methyl transferase	Vitamin E supplement
Sugar beet	Sucrose-sucrose fructosyl transferase	Fructans-low calorie alternatives to sucrose
Rice	Ferritin	Iron supplement
Potato	Antisense threonine synthase	Increased methionine levels
Potato	Seed albumin	Protein with all essential amino acids
Tomato	S-Adenosylmethionine decarboxylase	Increased lycopene levels
Tomato	Chalcone isomerase	Flavanols-act as antioxidants, reduce risk of cancer, heart diseases
Arabidopsis	Isoflavone synthase	Isoflavones-reduce serum cholesterol, and reduce osteoporosis
Canola	Modified acyl-acyl carrier protein thioesterase	*cis*-Stearates-lower the risk of heart diseases
For increased crop yield		
Rice	Phosphoenol pyruvate carboxylase	Increased efficiency of photosynthesis
Tobacco	Phytochrome A	Avoids shades
Lettuce	Gibberellic acid (GA) oxidase	Inhibits GA accumulation and stem growth (dwarfing)
Potato	Phytochrome B	Increased photosynthesis and longer life span
Others		
Tobacco and soybean	Cytochrome P_{450}	Synthesis of epoxy fatty acids for manufacture of adhesives and paints
Rice	Nicotianamine aminotransferase	Tolerance to low iron availability
Tobacco	Nitroreductase	Reduces land contamination by trinitrotoluene

GENETIC ENGINEERING TO INCREASE VITAMINS AND MINERALS

The transgenic rice (Golden Rice) developed with high provitamin A content is described above. Transgenic crop plants are also being developed for increased production of other vitamins and minerals.

A transgenic *Arabidopsis thaliana* that can produce ten-fold higher ***vitamin E*** (α-tocopherol) than the native plant has been developed. This was done by a novel approach. *A. thaliana* possesses the biochemical machinery to produce a compound close in structure to α-tocopherol. A gene that can finally produce α-tocopherol is also present, but is not expressed. This dormant gene was activated by inserting a regulatory gene from a bacterium. This resulted in an efficient production of vitamin E.

Some workers are trying to increase the mineral contents of edible plants by enhancing their ability to absorb from the soil. Some success has been reported with regard to increased concentration of iron.

COMMERCIAL TRANSGENIC CROP PLANTS

The very purpose of production of transgenic plants is for their commercial importance with high productivity. It was in 1995-96, transgenic plants