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The Science Behind Golden Rice

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Abstract: Rice is one of the staple foods all over the world. Normal white rice does not contain β – carotene and vitamin A. As many people in the world including children have a deficiency of vitamin A, researchers found a way to reduce the deficiency of it by genetically engineering normal rice and forming a new variety of rice known as golden rice. Deficiency of vitamin A results in health problems such as partial or complete blindness. Golden rice (*Oryza sativa*) is produced to biosynthesize β – carotene. β – carotene is a precursor of vitamin A. The golden rice technology has been given to all the countries by its inventors to fight against vitamin A deficiency. In this review paper we will understand the science behind golden rice.

Index Terms **- Golden rice, β – carotene, vitamin A, phytoene synthase, carotene desaturase, lycopene β – cyclase.**

I. INTRODUCTION

Biotechnology is a biology – based technology which helps modify products available in the nature into better or more efficient ones and make life better. Golden rice is one such boon of biotechnology [1]. Genetic engineering has made it possible to make life better. Vitamin A (Retinol) is one of the major deficiencies which is seen in children. It can cause blindness at a younger age. Lack of vitamin A also reduces the body's ability to fight diseases, thereby reducing the body's immunity. To maintain the epithelial lining of the body, this vitamin is needed [5, 6]. It also helps in cell growth and maintaining good health of the vital organs in the body. As vitamin A is found mostly in animal products, many people do not get a sufficient intake of it. None of the plants contain it, therefore there was an idea of producing a food product which contained a source of vitamin A [4].

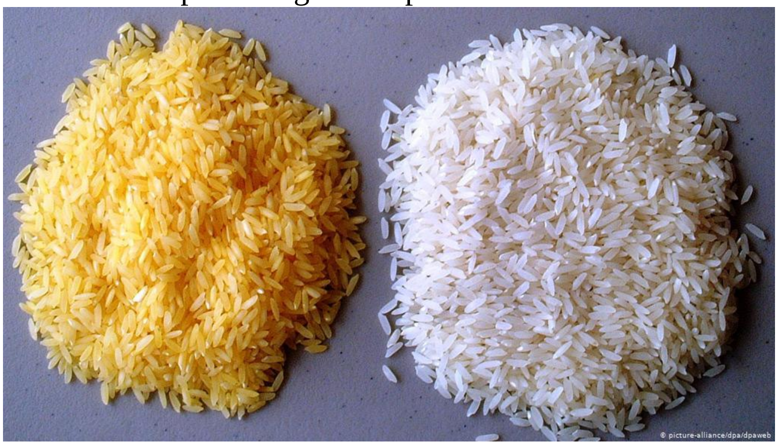

Figure 1 Golden Rice (left), Normal Rice (right)

The inventors of Golden Rice Professors Ingo Potrykus and Peter Beyer donated the technology behind making it to all the countries who willing to eradicated the deficiency of vitamin A. As rice is one of the main ingredients in food, researchers genetically engineered rice to make it more nutritious. Golden rice is genetically modified also known as biofortified to increase the content of vitamin A in it. β – carotene is synthesized during the seed maturation phase. The β – carotene is converted to vitamin A after consumption. It is β – carotene that gives the white rice a golden colour. β – carotene has numerous health benefits which include a positive effect on the cognitive function and memory, it provides protection to the skin against UV radiation, and a few researches also state that it prevents certain types pf cancer. Study says that if 40 grams of golden rice is consumed every day, it can cure the deficiency of vitamin A [3]. The cost of production of Golden rice won't be higher than normal rice as the harvested seeds can be replanted to produce more crops. The mechanism of conversion of β – carotene to vitamin A is illustrated in figure 2 [4].

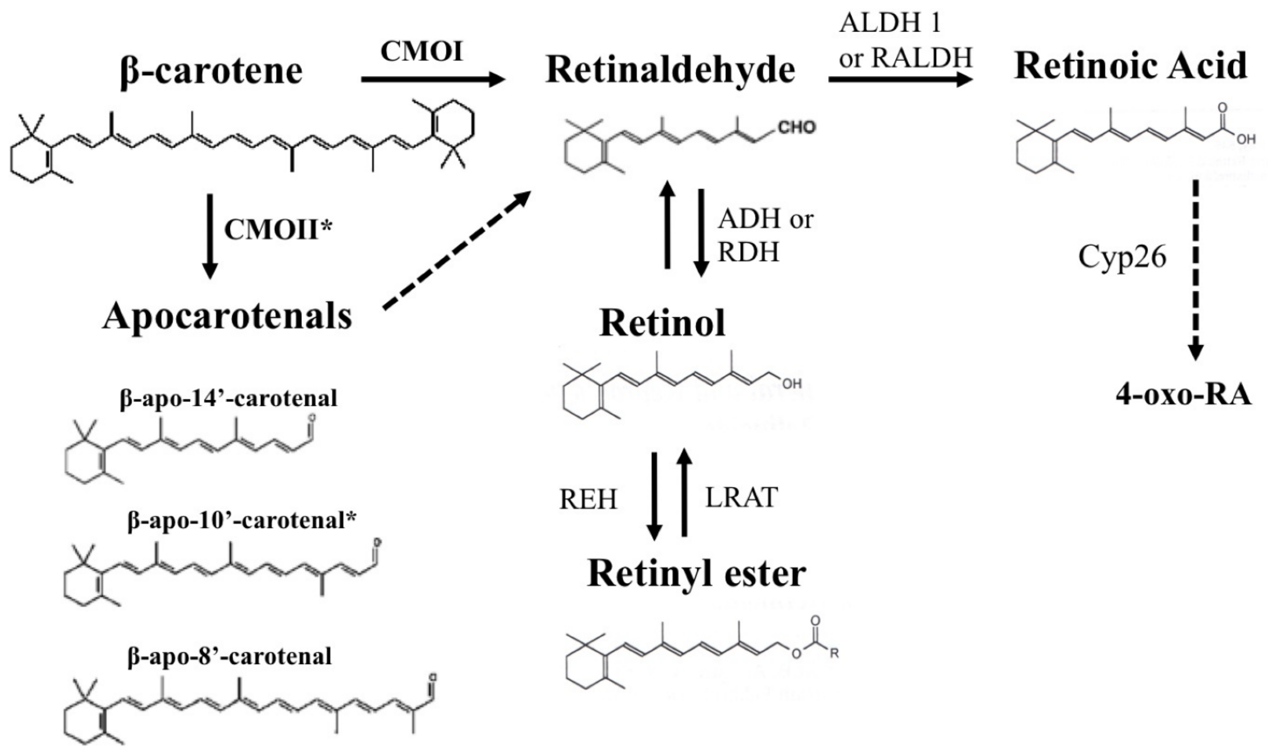

Figure 2 Conversion of β – carotene to Vitamin A (Retinol) [12]

II. Production of Golden Rice

The synthesis of lycopene and β – carotene develops from the isoprenoid pathway. The sequential addition of 5 – carbon isoprenoid units (isopentenyl diphosphate (IDP)) and dimethylallyl diphosphate (DMADP)) to form 10 – carbon (geranyl diphosphate (GDP)), 15 – carbon (farnesyl diphosphate (FDP)) and 20 – carbon (geranyl geranyl diphosphate (GGDP)) units are an important starting point for the synthesis.

The biosynthetic pathway of vitamin A is a continuation of the lycopene pathway. Immature rice endosperms are capable of synthesizing geranyl geranyl diphosphate, but subsequent stages of the pathway are not expressed in this tissue. A phytoene synthase (psy) gene from daffodil fused to a rice endosperm – specific promoter indicate that phytoene can be synthesized from GGDP in the rice grain. But, three subsequent steps are required to convert phytoene to β – carotene, these are phytoene desaturase & β-carotene desaturase to introduce the double bonds to form lycopene, improvement of crop yield and quality lycopene β – cyclase to form the rings in β – carotene. A bacterial carotene desaturase gene is capable of introducing all four double bonds that can be substituted for the phytoene desaturase and β – carotene desaturase. However, the transformation of normal rice to Golden Rice requires the introduction of three genes namely phytoene synthase, carotene desaturase and lycopene β – cyclase [7, 8].

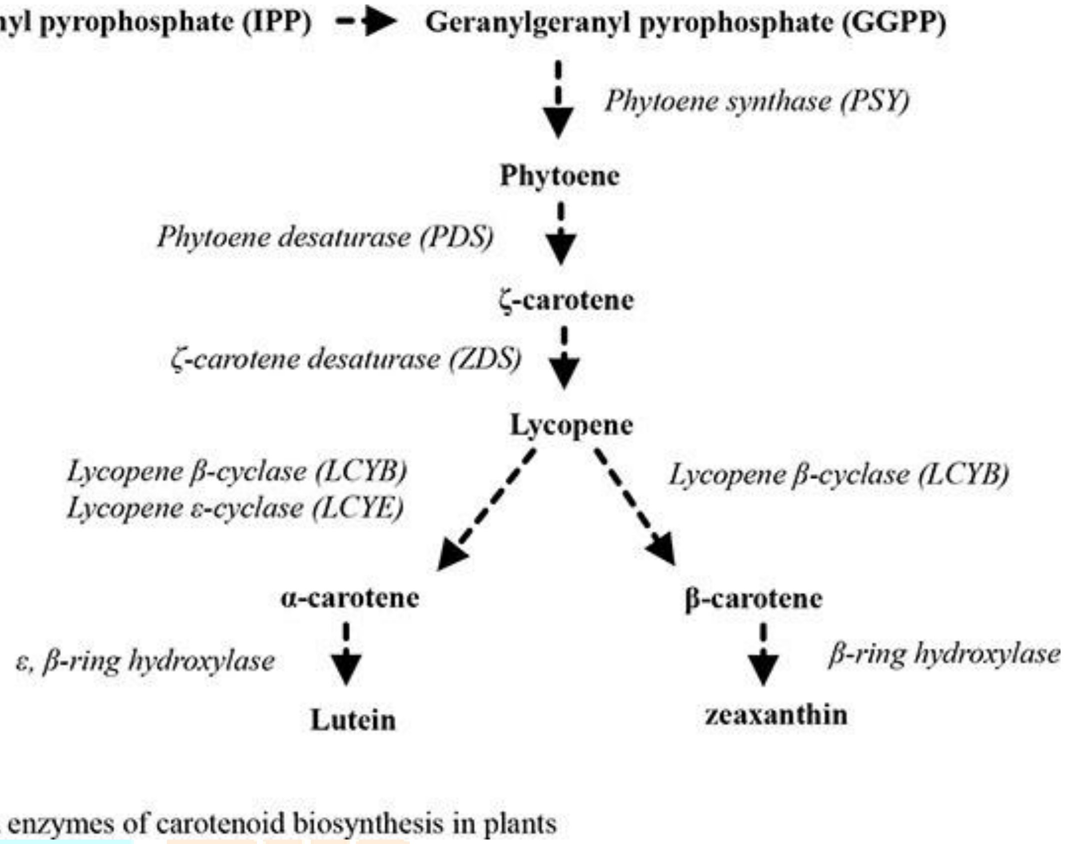

Figure 3 Biosynthetic pathway of β – carotene

Glutelin promoter construct was inserted into the vector pZPsC, along with a bacterial carotene desaturase gene (ctrl) from Erwinia uredovora, they were controlled by the 35S promoter. Both the enzymes were targeted by a plastid which was the psy gene. The lycopene β – cyclase gene from daffodil with a functional transit peptide was inserted into the vector pZLcyH under the control of a rice endosperm – specific glutelin promoter. This was accompanied by a hygromycin – resistance selectable marker gene.

The immature embryos of rice were inoculated with a mixture of Agrobacterium containing each of the two plasmids. 60 hygromycin – resistant regenerated lines were selected. All were shown to contain the pZCyH construct. Of these, 12 were also found to contain the pZPsC vector. Most of the seeds contained both the constructs which were found to be yellow, this indicated the presence of carotenoid. The highest producing line of this type was found to contain 1.6 μg β – carotene g^{-1} endosperm from a mixed population of segregating grains. It is therefore calculated that the homozygous grains of the same line should produce at least 2 μg g^{-1} vitamin A, which corresponds to 100 μg retinol equivalent to the daily intake of a person consuming 300 g rice per day. This is sufficient to make a significant contribution to the daily intake of vitamin A, though it is probably not enough to provide the complete dietary requirement of the vitamin [9, 10, 11].

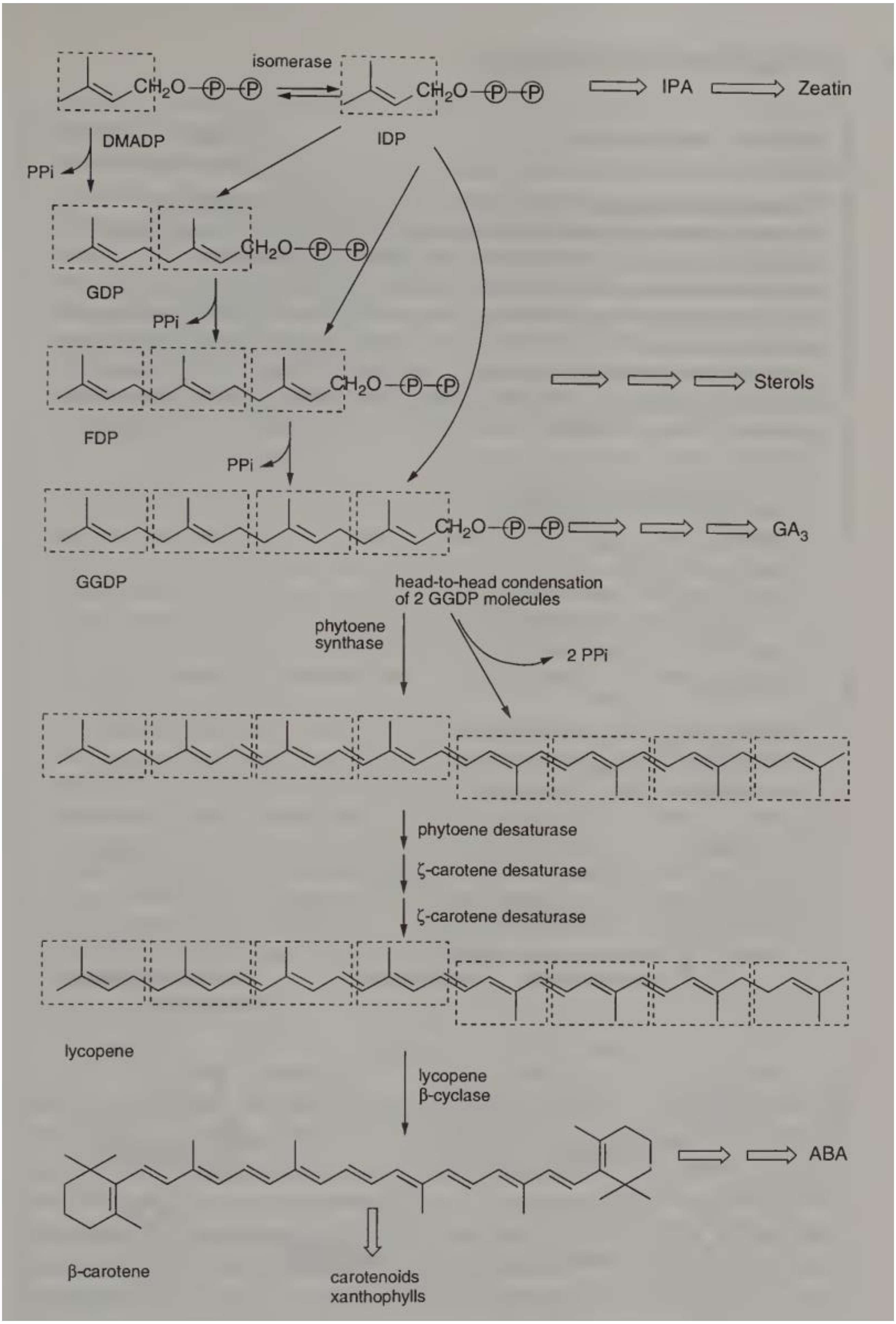

Figure 4 Elaborated Biosynthetic Pathway of β – carotene [11]

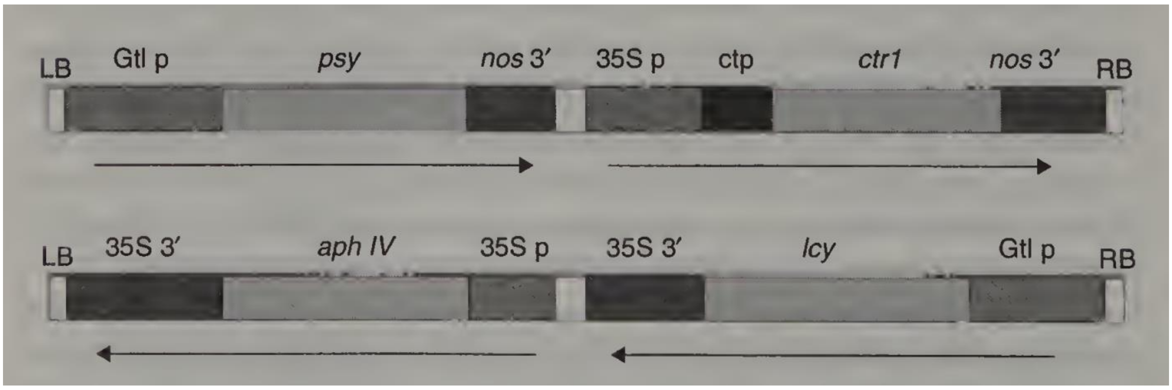

Figure 5 Constructs for the production of Golden Rice [11]

The two independent constructs used for Golden Rice production were the most successful strategy. The first construct consisted of a daffodil phytoene synthase (psy) gene fused into a rice glutelin promoter in sequence with a bacterial carotene desaturase gene (ctr 1) driven by the 35S promoter. The second one consisted of a hygromycin – resistance aph IV selectable marker gene in sequence with a lycopene β – cyclase gene (lcy) of daffodil also fused to an endosperm – specific rice glutelin promoter [11].

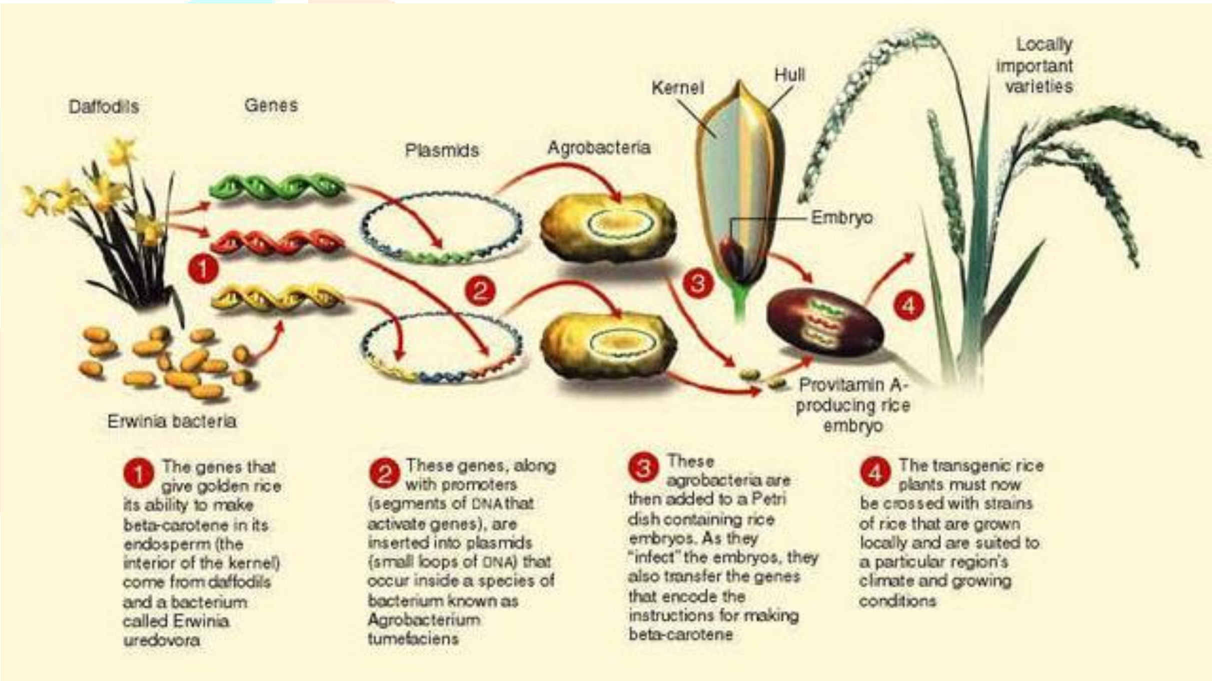

Figure 6 Summary of the Production process for Golden Rice

III. ADVANTAGES & DISADVANTAGES OF GOLDEN RICE

Advantages

1. Combats malnutrition
2. Reduces preventable blindness
3. Improves the economy of the country
4. No environmental risks and damages [2]

Disadvantages

1. It can be used as a means for corruption
2. Can be counter – productive for commercialization [2]

IV. CONCLUSION

Research has made it clear that the conversion of β – carotene to vitamin A is successful in Golden Rice. In other food items which contain β – carotene, the conversion is not efficient. This research has been an advantage and a lot of intensive work has been seen in the production. However, it is still difficult to get a laboratory – scale method to provide the Golden Rice to common man. With more research in this field, there will be a change in the society [2, 11].

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