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Golden Rice and Its Prospects in Nepal

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ABSTRACT
Vitamin A deficiency (VAD) is public health problem and a preventable cause of death of poor and farm families especially the women and children in many parts of developing countries. It is endemic in countries where rice is the staple diet and food sources of Vitamin A are inadequately consumed. β-carotene, precursor of Vitamin A, if can be enriched in the endosperm of rice grains, helps to combat VAD in areas where rice is a major commodity. A yellow-coloured transgenic rice variety, called First Generation Golden Rice (GR1), was developed by introducing two foreign genes, namely Psy and CrtI gene from daffodil and bacterium Pantoeaananatis (previously known as Erwiniauredovora) respectively. Later, Second Generation Golden Rice (GR2) with increased β-carotene from 1.6μgg^{-1} to 31μgg^{-1} was developed using Psi gene from maize instead of daffodil. Supporters of GR2 claim that it is sustainable, practical and cost-effective method of combating VAD while the oppositions question its' productivity, consumer acceptance, stability of β-carotene over storage and cooking, environmental and health impacts, etc. All these concerns should be satisfactorily answered before introduction and commercial cultivation of Golden Rice in Nepal.
Key Words: Golden rice, genetic engineering, β – carotene, transgene, biosynthesis

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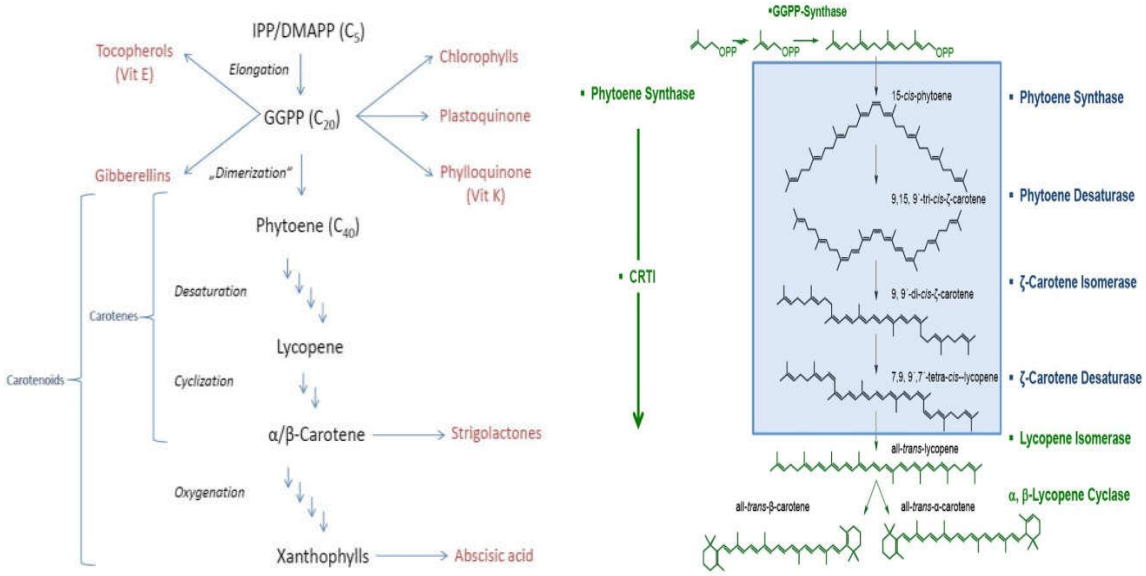
INTRODUCTION

Golden rice (*Oryzasativa GR*) is genetically engineered rice which is capable to synthesise β-carotene in the grains thus imparting it a golden yellow colour. Since, conventional breeding methods were not sufficient, recombinant technology was used to introduce foreign genes capable of coding the biochemical synthesis of β-carotene.

Vitamin A deficiency (VAD) is a major nutritional concern in poor societies, especially in lower income countries. The main underlying cause of VAD as a public health problem is a diet that is chronically insufficient in vitamin A. Severe deficiency of Vitamin A causes xerophthalmia, the leading cause of preventable childhood blindness, anaemia, weakened immunity against infections and risk of death (WHO Report 2005). Vitamin A deficiency (VAD) is responsible for 500,000 cases of irreversible blindness and up to 2 million deaths each year. Particularly susceptible are pregnant women and children. Across the globe, an estimated 19 million pregnant women and 190 million children suffer from the condition (The Golden Rice Project).

Breeding Development of Golden Rice

The immature rice endosperm can endogenously synthesize an early intermediate geranylgeranyl-diphophate (GGPP). Two transgenes were required to be introduced to complete the biosynthesis of β-carotene. The first transgene encodes a plant phytoene synthase (PSY), which utilises the endogenously synthesised geranylgeranyl-diphosphate (GGPP) to form phytoene, a colourless carotene. The second gene encodes a bacterial carotene desaturase (CRTI) that introduces conjugation by adding four double bonds*(Burkhardt et. al., 1997).* Thus, the combined activity of PSY and CRTI results in the formation of lycopene, a red compound popularly known in tomato fruit. However, lycopene has never been observed in any rice transformants. Instead, α- and β-carotene are found together with xanthophylls. It is revealed that the pathway proceeded further and beyond the action of these two transgenes. This is the reason behind the golden yellow colour of this transformant rice instead of redcolour.(*Schaub et al., 2005*).



(Retrieved from: http://www.goldenrice.org/Content2-How/how1_sci.php)

Initially, experiments of Golden Rice development were carried out in Japonica cultivar Taipei 309 and until now, it is successfully achieved in a number of different Japonica and Indicavarieties (Hoa et. al. 2003).

During the early development of Golden Rice, the β-carotene level in it was very low (1.6μgg^{-1}) which would not suffice the daily provitamin A requirements unless supplemented by other sources. This early version of Golden Rice, popularly known as First Generation Golden Rice (GR1), contained phytoene synthase (Psy) gene from daffodil and carotene desaturase (CrtI) gene from bacterium *Pantoeaananatis* (previously known as *Erwiniauredovora*). As GR1 containedvery limited amount of β-carotene, ways to increase the β-carotene content were extensively studied and new lines, called Second Generation Golden Rice (GR2), that are more efficient for β-carotene accumulation (31μgg^{-1}) were developedreplacing Psy gene from daffodil by the same gene from maize.

Arguments: Supporters versus Opposition

Golden Rice has acquainted a huge excitement from the beginning of its development and still the excitement level is not lowered. Strong arguments are raised both in favour and opposition of releasing golden rice cultivars for the commercial production. The supporters of Golden Rice claim that it can be the single most potent tool to combat VAD induced diseases especially in those parts of the world where rice is the staple diet. Various efforts like distribution of vitamin supplements, industrial fortification of foodstuffs and increasing consumption of diversified food are carried out to reduce deficiency of vitamin A but the cost-effectiveness and sustainability of these programs are in question. Small countries like Nepal require about 2 million dollars every year to run these campaigns while highly populated countries like India cannot afford the prohibitive costs of such nation-wide programs (UNICEF, Micronutrient Initiative). *Golden Rice 2* promises to be very cost effective.Bioavailability studies indicate that regular consumption of *Golden Rice* will be able to provide the recommended dietary allowances (RDA) in societies having rice based food habits. β -Carotenederivedfrom Golden Riceis found to be effectively convertedtovitaminAinhumans.100 g uncooked rice provides 500–800 μg retinol. This represents 80–100% of the estimated average requirement (EAR) for men and women and 55–70% of the Recommended Dietary Allowance (RDA, derived from the EAR) for men and women (Tang et. al.). 72g of dry GR2 polished rice would provide 50% of RDAof vitamin A for children (Paine et. al. 2005).

Although studies suggest the beneficial aspects of Golden Rice in combatting VAD and saving lives of millions of men, women and children, there are still some bottlenecks in commercial success of Golden Rice. Golden Rice is always sceptically viewed as a product of genetic modification. The anti-GMO campaigns throughout the world challenge the release and development of Golden Rice. The cultural and social factors may also discourage its adoption. The consumer acceptance of yellow rice instead of white rice is not ensured. The productivity of Golden Rice varieties is very poor in comparison to the modern commercial varieties. The stability of β-carotene in long term storage and traditional cooking methods is yet again questionable. Detail studies about the long term effects of cumulative and regular consumption

of Golden Rice are yet to be carried out. There are very strong ethical concerns about Golden Rice like intellectual property rights, the future environmental impacts, escaping of genes from the GMO to other varieties, the possibility of herbicide and/or pesticide resistance and inadvertent future harms to biodiversity.

Prospects in Nepal

Vitamin A Deficiency and its manifestations are among the major health problems primarily of women and children in Nepal.Nepal is one of 60 countries in which the vitamin A deficiency constitutes a significant public health problem. Each year in Nepal, vitamin A deficiency is responsible for the deaths of 9000 children and for 2500 children becoming permanently blind. 8.5% of Nepalese children and 7% of pregnant women are suffering from VAD induced disorders.An interesting question arises: Can Golden Rice minimize VAD inducedproblems in Nepal?

Although rice is the staple food of Nepal, it is generally not eaten alone. Bhat (rice), Dal (pulses) and tarkari (vegetables) together constitute the major food of Nepalese people which is itself rich in vitamin A content. So, it is questionable that introducing Golden Rice in food habits of Nepalese people will contribute toour struggle against VAD.In context of Nepal, it is evident that the people who don't have rice based food habit occupy the larger portion of population affected by VAD. Also, the large part of the affected population lives in mountainous region where rice cannot be grown. Poor people in these regions can neither grow nor afford Golden Rice, if introduced. The transportation of Golden Rice from terai to hills and mountains would againmake it unaffordable and inaccessible. It might turn out into a mere loss of energy and resources. So, it seems that Golden Rice is not the absolute solution that Nepal needs to win the battle against VAD. On the contrary, encouraging the production, distribution and consumption of fortified maize would be easier for reducing VAD induced problems in hilly region of Nepal. There is no any history of introduction of GMO'sin Nepal. Besides, there is not even in-depth study conducted about farmers' response towards GMO's. So, the adoption rate of Golden Rice in Nepal is highly unpredictable. It is necessary to have knowledge about the perception of farmers and consumers towards Golden Rice. The media response and public voices indicate that Nepalese society is likely to turn out unwelcoming towards GMO's, be it Golden Rice.On the other hand, the previously mentioned obstacles in global production, release and adoption of Golden Rice are equally significant in Nepalese context as well.

CONCLUSION

The development of Golden Rice has opened an entirely new horizon in modern breeding technology. The scientific knowledge of genetic engineering and its practical implications are of great value for crop biotechnology and nutrition breeding. The superiority of Golden Rice as a tool to combat VAD is yet to be proved. Golden Rice may not be the correct weapon that we actually need to fight against VAD in Nepal. It can be concluded thatthere are still many scientific, cultural, political and ethical questions to be justifiably answered before introducing Golden Rice for commercial production in Nepal.

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