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Mini Review

Genetically Modified Crops: Present and Future Perspective

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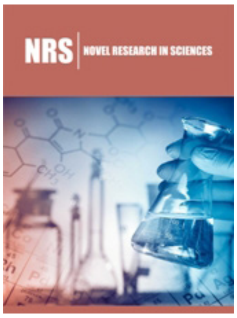

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Mini Review

India occupies a prominent position in the World as 1st prime producer of fruits and vegetables, its production of fruits and vegetables during 2018-19 which is around 314.5 million tons (mt) [1]. Further, India ranks first in the production of some important tropical fruits in innumerable varieties. We incur an enormous loss in our total production, which is estimated to be nearly 30-40%, causing drastic loss to fruit and vegetable industries. Genetically modified (GM crops can help us to meet the demand of high yielding, nutritionally -balanced, biotic and abiotic stress tolerant crop varieties [2].

Agricultural biotechnology is a great boon for humanity for addressing novel approaches for high yield, at low cost to provide sustainable food, environmentally friendly with enhanced nutritional value. This technology is being used to develop new varieties and traits using genetics and genomics, marker-assisted selection, and transgenic (genetic engineered) crops. In recent years, development of transgenic crops with multiple beneficial traits has emerged as an important area in the field of plant biotechnology. Most of the progress through genetic engineering to date has been made in the area of improving the agronomic traits of crops. Our laboratory has been focused on improving post-harvest loss, tolerance to drought and phytopathogens, which significantly contribute to improvement in crop yield. Food and nutritional insecurity pose serious concern for human health worldwide, especially in developing countries due to continuous rise in population growth. Therefore, promoting the nutritional value of staple crops is a major consideration for global food and nutritional security. The recent achievements in plant biotechnology has opened immense possibilities and scope for obtaining crops with better quality and improved productivity and scope for nutritional and food security worldwide.

For the first time, Prof. Datta's laboratory has identified and cloned *AmA1* from Amaranth that encodes a 35-kDa protein rich in essential amino acids. Amaranthus is a cosmopolitan genus of annual or short-lived perennial plants known as Amaranths. It belongs to kingdom Plantae, family Amaranthaceous and genus Amaranthus [3-15]. AmA1 composition was found to be even better than that recommended by the WHO for a protein to be optimum for human nutrition [4-6,15-18]. In order to enhance protein content in potato, we used *AmA1* gene. The field performances of *AmA1* potatoes at different agro-climatic conditions were found to be consistent over the years. The agronomic performance and nutritional equivalence study of the GM potato varieties (seven Indian commercial potato cultivars) have been proved its safe consumption.

Fruit ripening, softening and subsequent spoilage need to be controlled for extension of shelf-life and effective preservation. Recently two N-glycan processing enzymes α-mannosidase (α-Man) and β-D-N-acetylhexosaminidase (β-Hex) were targeted in Prof. Datta's laboratory to control fruit softening during ripening. His group cloned and patented α-*Man* and β-*Hex* genes [7-8,18-23]. Further, silencing of α-*Man* and β-*Hex* genes in transgenic tomato plants using RNAi technology resulted in enhanced fruit shelf life, due to the reduced rate of fruit softening. Transgenic tomatoes were found to be ca. 2.5 and 2-fold firmer in the case of α-Man and β-Hex suppressing RNAi lines, respectively. Transgenic tomatoes exhibited ca. 40-45 days of prolonged shelf life whereas no negative effect on phenotype, including yield and nutritional value. The results revealed a stable and heritable transfer of character and now they have successfully conducted 9th generation field trials. Further, obtained seeds will be used to raise next generation transgenic lines in the experimental plot Figure 1.

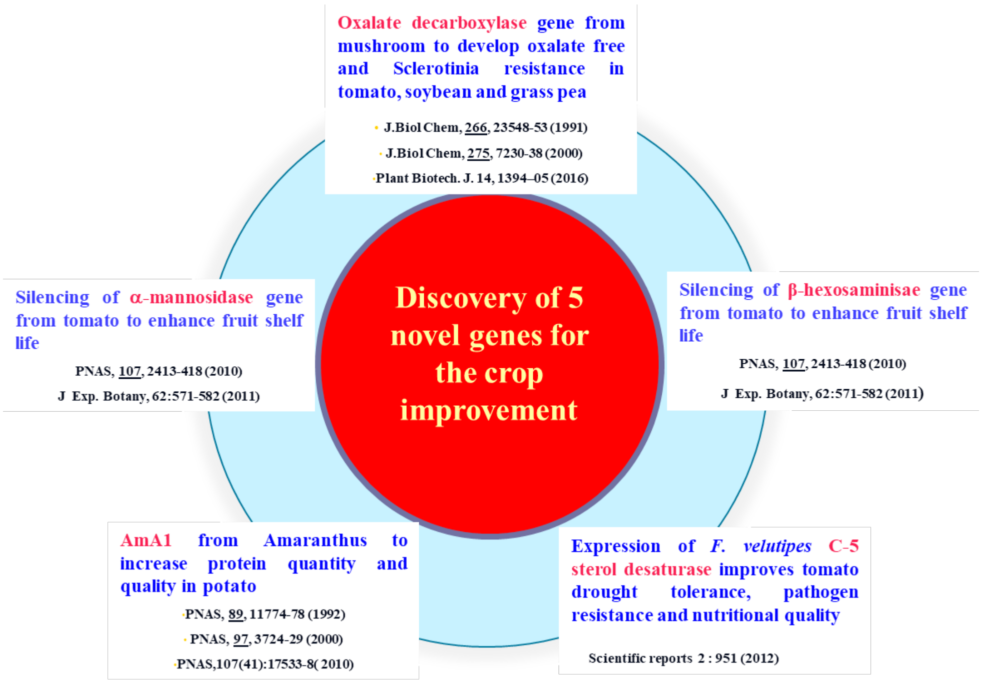

Figure 1.

In order to generate tomato with improved drought tolerance, resistance to phytopathogenic fungus *S. sclerotiorum* along with the increased iron and polyunsaturated fatty acid (PUFA) content by expressing a single gene encoding C-5 sterol desaturase (Fv*C5SD*) from an edible Mushroom *Flammulina velutipes* [9-11,18-23]. The seventh-generation field trials of these transgenic lines are being carried out. They are now using this strategy for rice, soybean, grass pea etc.

Some crops e.g. tomato, soya bean and grass pea are rich sources of vitamin, minerals and proteins but they contain oxalic acid as a nutritional stress factor because oxalate chelates calcium and precipitation of calcium oxalate in kidney leading to hyperoxaluria and destruction of renal tissues leading to Nephrolithiasis. Nephrolithiasis is caused due to the formation of calcium oxalate crystals in kidneys. His laboratory has discovered Oxalate decarboxylase (OXDC); the gene encoding oxalate decarboxylase has opened up a new area of research, which is relevant to human health [11].

Oxalate-free transgenic tomato

By expressing an oxalate decarboxylase (*FvOXDC*) gene into tomatoes fungal resistance is conferred with reduced oxalate level [12,13]. The 9th field trial of oxalate-free GM tomato lines was carried out. The studies on food value, food safety, toxicity and allergenicity associated with transgenic tomatoes have been completed. The obtained seeds will be used to raise next generation transgenic lines in the experimental plot.

Oxalate free transgenic soya bean

Prof. Datta's laboratory has developed transgenic soya bean by expressing an *FvOXDC* and reported significant reduction in oxalic acid level in soya bean seeds (up to 73%) and improved tolerance to the fungal pathogen *Sclerotinia sclerotiorum* [14]. The transgenic soya bean plants have completed more than seven years under restricted field trial.

Transgenic Lathyrus without neurotoxin

Lathyrus sativus (grass pea) has high protein content, good grain yield, resistance to insects and pests. But it also contains anti-nutritional metabolite oxalic acid. Oxalic acid is also known as precursor of β-N-oxalyl-L-α,β-diaminopropionic acid (β-ODAP), a neurotoxin found in lathyrus. Prolonged consumption of grass pea causes neurolathyrism, which is characterized by spasticity of leg muscles, lower limb paralysis, convulsions and death [14]. Prof. Datta's laboratory has developed fungal resistant transgenic grass pea by expressing *FvOXDC* with reduced oxalic acid (up to 75%) and β-ODAP (up to 73%) in grass pea. The transgenic grass pea plants have completed more than 7 years under restricted field trial.

Summary

Prof. Datta's laboratory is involved in the area of nutritional genomics. One of the goals of nutritional genomics has been to create crops (genetically modified) that are tailored to provide better nutrition for human beings and domesticated animals (nutritional security). He is known for his pioneer contributions in molecular biology and identification and manipulation of novel genes leading to the production of transgenics of high societal value. His outstanding achievements of global impact include: isolation of *AmA1* gene (First international gene patent from India; US patent No. 5670635, 5849352, 5846736) and production of transgenic potato with enhanced protein content with considerable increase in the amount of essential amino acids. Field trial of India's first GM crop with high nutritional value is over now. The agronomic performance and nutritional equivalence study of the GM potato varieties have proved its safe consumption. The compilation of the work is going to be placed to Regulatory Committee for approval very soon for large-scale cultivation. This opens up a new dimension in global challenge to create new breeds of value-added crops for better human nutrition and animal feed**.** Another major discovery from Prof. Datta's lab has been the discovery of oxalate decarboxylase (OXDC) gene from edible mushroom. This discovery of *OXDC*, the gene encoding oxalate decarboxylase has opened up a new area of research, which is relevant to human health. Some green leafy vegetables (e.g. Amaranthus, spinach, rhubarb) are rich sources of vitamins and minerals but they contain oxalic acid as a nutritional stress factor because oxalate chelates calcium and precipitation of calcium oxalate in kidney leads to hyperoxaluria and destruction of renal tissues. Moreover, the production of oxalic acid is an important attacking mechanism utilized by *Whetzelinia sclerotiorum*, a fungus which causes serious damage to crops like sunflower. His group has developed oxalate-free transgenic tomatoes using oxalate decarboxylase gene. The promising transgenic tomato plants have completed fourth restricted field trial. Therefore, the development of GM tomatoes with *OXDC* gene, their field resistance and agronomic potential has a high impact not only in Indian agricultural biotechnology but worldwide against protection for *Sclerotinia*, a devasting fungal pathogen for a wide range of agricultural crops. Consumption of *Lathyrus sativus* (Kesari Dal) causes neurolathyrism, which is characterized by spasticity of leg muscles, lower limb paralysis, convulsions and death. The neurotoxin, β, N-oxalyl, L-α, β-diamino propionic acid (ODAP) is synthesized from oxalic acid. In order to remove ODAP, his group has developed low oxalate transgenic grass-pea (Lathyrus) using OXDC gene which has completed 7^{th} year restricted field trial. His unique achievements from isolation of two novel genes to production of transgenics and their field release have all been carried out solely by his group. In addition, a unique achievement of Prof. Datta's work has been silencing of novel fruit ripening genes, α-mannosidase and β-hexosaminidase, isolated by his lab leads to enhanced shelf life of fruits and vegetables. His pioneering and original work opens up a new dimension in global challenge to create new breeds of value-added crops for better human nutrition and increased productivity. His findings will have a great impact on the lives of the vast population in developing and underdeveloped countries.

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