iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** X **Month of publication:** October 2020

DOI: https://doi.org/10.22214/ijraset.2020.31970

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue X Oct 2020- Available at www.ijraset.com

Genetically Modified Crops - Answer to India's Hunger Crisis?

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Abstract: Falling under Global Hunger Index of 94 as per latest reports, India has to move way forward to curb the problem of food insecurity. Shifting from conventional to advanced agricultural practices, human civilisation has come a long way to deal with the issue. The rise of genetically modified crop (GM Crop) variants has gained importance in the recent times. They not only provide a method for food security but also have opened up ways to the proper utilisation of agricultural practices. This review aims to discuss the important aspects with relation to GM Crops, Food Irradiation and could it be a crucial alternative.
Keywords: Food Insecurity, Agriculture, GM crops, Food Irradiation

I. INTRODUCTION

India records a population of 1.33 billion, which corresponds to the number of mouths to feed. India's increasing hunger and food insecurity is a major concern which is rising at an alarming rate. The *International Food Security Assessment, 2013-23* by USDA have estimated India's food-insecure population at 255 million, and about 36.1 percent of the 707 million food-insecure people among the 76 low-income countries studied. The Government of India conducted a survey using a measure of poverty based fundamentally on the cost of a nutritionally balanced diet, 355 million Indians, or 29.8 percent of the population, lived in poverty in 2009/10 [1].

Scientific advances in biotechnological research have culminated in the genetic engineering or modification of crops. It offers techniques to accelerate the efficiency and extent of further crop improvement by the alteration of genes conferring resistance to insects, crop diseases, herbicides and biotic and abiotic stress, as well as qualitative traits such as improved shelf life post-storage, flavour, nutritional content and colour. The resulting germplasm is anticipated to allow agriculturists to respond much more efficiently to the need for new and improved cultivars, and satisfy the increasing consumer demand for a consistent supply of surplus grains, fruits and vegetables with reduced effects from pests/diseases and reduced pesticide residues [2].

Malnutrition is the medical term used for hunger. India experiences a burden of malnourishment amidst its population of children less than five years of age. As recorded in 2015, the national pervasiveness of under-five that are overweight is 2.4%, which has increased minutely from 1.9% in 2006. The national prevalence of under-five stunting is 37.9%, which is exceeding the developing country average of 25%. India's under-five wasting prevalence of 20.8% is also surpassing the developing country average of 8.9%. Undernourishment also magnifies the impact of diseases, including measles and malaria which are prevalent across India [3].

Biotechnology offers a very promising alternative to genetically engineered foods and an enhancement on conventional plant-breeding techniques. If amalgamated with other relevant agricultural technologies, it provides an exciting and environmentally responsible way to meet consumer demand for sustainable agriculture. More green revolutions can be expected when the benefits of GM crops will reach small scale farmers. However, there are concerns directing towards a technological scenario controlled by private firms and Intellectual Property Rights. Patents offer substantial rights over seeds and plant genes which have worrisome implications. If farmers have to purchase seeds during every sowing season, it will affect their income and food security [4]. And India Brand Equity Foundation (IBEF) has 16.6 million farmers and 131,000 traders registered on its platform until May 2020 [5].

II. AGRICULTURE: THE BACKBONE of INDIA

The age-old practice of Agriculture, also referred to as farming, is the production of food for the entire human population. Humans depend on plants for food so harvesting in a better way has always been the aim. Agriculture is a worldwide practice. In day-to-day life activities, agricultural products play an important role. When you think of agriculture, think of the five F's: food, fabric, forestry, farming, and flowers.

History evidences of agriculture can be traced from the Fertile Crescent. It has often been called the "Cradle of Civilization" as well, since both the wheel and writing first appeared there.

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Humans invented agriculture during the Neolithic era, or the New Stone Age, which occurred between 7,000 and 10,000 years ago. The Bronze Age brought about changes in advanced metalworking techniques, creating ever-stronger farming implements. In the Middle Ages, farmers from Europestarted using complex irrigation systems. Between the 17th century and the 19th century Britain experienced a dramatic increase in agricultural productivity known as the British Agricultural Revolution [6].

The technology of agriculture has continued to evolve over the years. Taking into account of India, it has achieved grain self-sufficiency but the production yet remains resource intensive, cereal centric and biased with different locations. The resource intensive ways of Indian agriculture have raised serious sustainability issues too. Changes has to be made taking into account the water resources of the country or else sustainability would be far to attain. Deforestation and reducing land quality also pose major threats to agriculture in the country which is why improvement is required in its management of agricultural practices on multiple fronts. Meanwhile, the development of hybrid seed—particularly hybrid corn—revolutionized agriculture.Hybrid seeds contributed to the increased agriculture output of the second half of the 20th century.

Future agricultureseems to use more advanced technologies such as robots, temperature and moisture sensors, aerial images, and GPS technology presently being tested by Indian Space Research Organization (ISRO). These advanced devices and precision agriculture and robotic systems will allow farms to be more profitable, efficient, safe, and environmentally friendly [7].

III. GENETICALLY MODIFIED CROPS (GM CROPS)

A. Intro

A GMO, or genetically modified organism, is a plant, animal, microorganism or other organism whose genetic makeup has been modified in a laboratory using genetic engineering or transgenic technology. This creates combinations of plant, animal, bacterial and virus genes that do not occur in nature or through traditional crossbreeding methods. To levitate the problem of hunger, the focus has shifted quite a bit towards the sector of Crop engineering.

Pros: GM foods are actually less costly so farmers are able to afford and grow them, which in turn makes the food cheaper for the consumers. GMO techniques may also enhance foods nutrients, flavor, and appearance.

Cons: India has denied allegations levied by the European Commission on genetically modified organisms (GMO) contamination in basmati rice exported from India [8][9].

GM crops have been flooding the Indian markets. This has led to increasing cases of crop failure and distress amongst the farmer community. But practicing permaculture, on the other hand, ensures fair trade for the farmers, as the input cost is less and it does not have the concept of loans and debts. As the farmers save the seeds and use it for next cropping season, the cases of capitalization of seed, branding and patenting will reduce and famers will have their own stocks [10][11].

B. Methodology

Traditional agricultural strategies have started to fall behind to meet the food and nutrition requirements for such a large population. Genetic technologies have thus become popular yet a necessity. We all know about ‘FlavrSavr’ tomato being the first transgenic fruit crop and was successfully commercialized by Bruening and Lyons from 2000 onwards. This led to emergence of various other GM Crops [12]. The basic methodology is shown as in Fig 1-

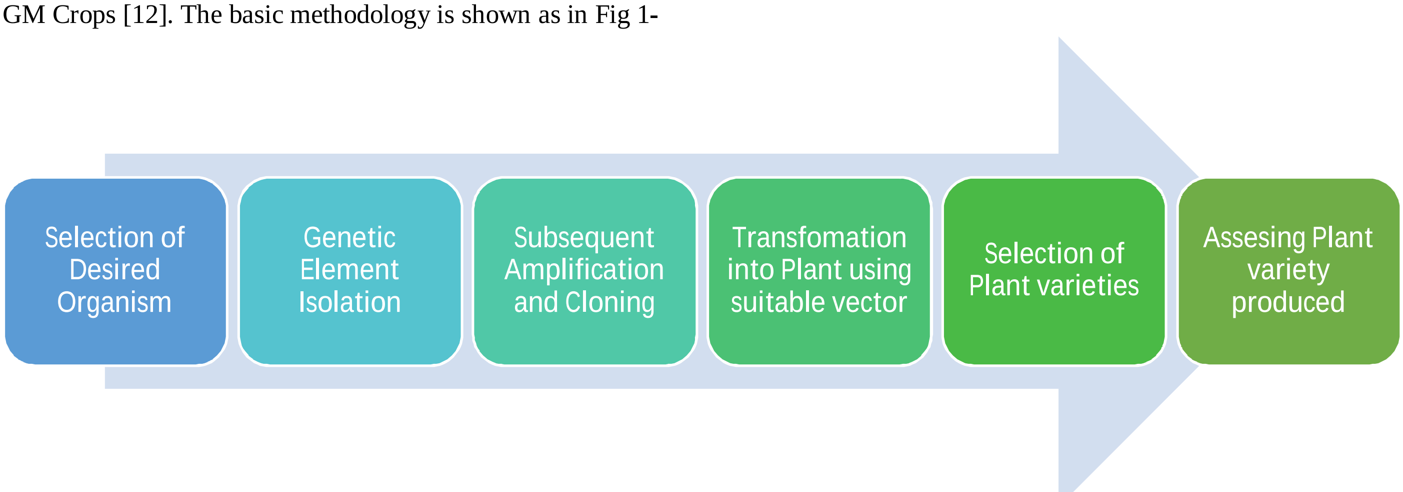

Fig. 1 Basic Methodology employed for GM Crop production

C. GM Crops in India

Bt Cotton became the only approved GM Crop in India till date after the Genetic Engineering Approval Committee (GEAC) gave its nod in 2002.Bt cotton derived its name from *Bacillus thuringiensis*, popularly known as the "plant genetic engineer". A genetic element was transferred from *Bacillus thuringiensis var. kurstaki* which has the ability of producing an insecticidal protein against larvae of Lepidoptera thus conferring protection to cotton against harmful insecticides (Fig. 2). Bt Brinjal was quite in the picture until it got banned and cultivating the same is a criminal offence under the Environment Protection Act, 1989. India along with 172 other countries signed the Cartagena Protocol on Biosafety which vows to ensure handling, transport and the use of modified organisms in a proper and safe manner [13].

(a)

(b)

Fig. 2 Comparative representation of Genetically Modified Crop with a normal variant (a) Non Bt Cotton (b) Bt Cotton (Source:Limbalkar Omkar Maharudra, "India: From BT Cotton to GM Mustard," *Biotecharticles.com*, 2017)

By resisting genetic engineering technologies, India risks falling behind the rest of the world where scientists are deploying gene editing tools to improve yields, disease resistance and shelf life of crops. Bhagirath Choudhary, Director at the Delhi-based South Asia Biotechnology Centre quoted that "A suit of gene editing technologies like CRISPR, TALENs will find no place in India if the policy paralysis continues on GM technologies in brinjal, mustard and cotton"[14].

D. Advances in Crop Engineering

Some of the other breakthroughs made possible several breakthroughs have been made over the passing years. Scientists group from Cinvestav-Langebio in Irapuato, Mexico have implemented gene editing technology for enhancing the fertilizer utilisation for a set of plant samples. More utilisation will mean less fertilizer use and eventually lower pollution induction. Plant Based Research Group from the Institute of Agricultural Technology of Argentina (INTA) have successfully attempted to edit the potato plants in order to halt the browning process of the same. American scientists claim to have developed "safer" genetically modified organisms (GMOs) that cannot spread in the wild. These GMOs have been created using synthetic biology. Farren Isaacs of Yale University who led one of the two studies quoted while interviewing with BBC that "What we've done is engineered organisms so that they require synthetic amino acids for survival or for life" [15][16].

IV. FOOD SECURITY STRATEGY

The Food and Agriculture Organisation (FAO) at the United Nations provides the well-accepted definition of food security: *"Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life."*. The concern for food security is as significant to India as it is for the rest of the world. According to the FAO, India has the largest no. of food insecure people despite its commendable economic growth in recent years [17]. Though the Green Revolution was fruitful in resolving the problem of production, now the troubles are different. Concerns of growing water scarcity, climate change and the ecological hazards due to the use of chemical fertilizers and pesticides are imminent. Use of new agricultural methods like organic farming, genetically modified crops, bio fertilisers are a must for ensuring food security. The post-harvest losses during storage of food are another problem [18]. This is where techniques like Food Irradiation for the preservation of food commodities become crucial.

A. Food Irradiation and Sustainability

Food irradiation or Radiation processing of food is the controlled application of energy from ionizing radiation such as gamma rays, electrons, and x-rays for food preservation. Gamma rays are emitted by radioisotopes like Cobalt-60 and Caesium-137 whereas electrons and X-rays are generated by machine sources working on electricity. The basic principle is that ionizing radiation damages the DNA of living cells very effectively.

When this radiation is absorbed by water and other molecules that make up our food, they interact with the DNA causing the death of micro-organisms, insects, and preventing plant meristems from reproducing. This ensures food safety by the elimination of insects and pathogens and various preservative effects as a function of the absorbed radiation dose. Radiation can be applied to fresh or frozen foods to sustain their shelf life without any impact on the nutritional value and sensorial properties. Unlike chemical fumigants, irradiation doesn't leave behind any toxic residues on the food. It is a very efficacious process and can be used to treat pre-packed commodities including those that can't withstand heat [19].

Radiation processing of food requires an irradiation chamber shielded by thick concrete walls to prevent the escape of any radiation outside the chamber to the work area or operator room. A Radiation Processing Facility plot is depicted in Fig. 3. Food commodities either pre-packed or in bulk are put in suitable containers and sent into the chamber by a conveyor belt so that human presence is not required inside the chamber. In the case of Gamma rays, the radioactive source is generally kept 6m under water which acts as a shield. For treating food, the gamma source is brought above the water level after all safety checks of the chamber. The containers or carriers of food are placed on a mechanical platform around the source and are rotated on their axis so that the contents are irradiated from all directions. Absorbed dose is checked by the dosimeters placed at suitable positions on the carriers. Hence the food never really comes in direct contact with the source [20].

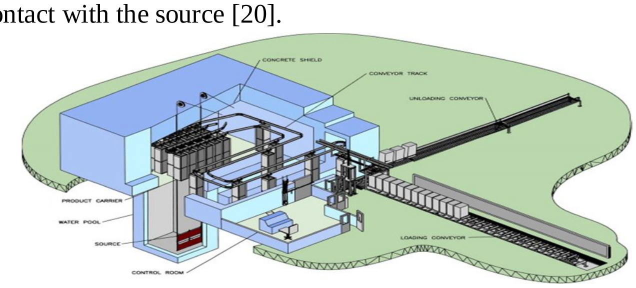

Fig.3 Chamber plot of a typical Food Irradiation Facility (Source: R. B. Solanki, M. Prasad, A. U. Sonawane, and S. K. Gupta, "Probabilistic safety assessment for food irradiation facility," *Annals of Nuclear Energy*, vol. 43, pp. 123–130, May 2012, doi: 10.1016/j.anucene.2012.01.002.)

The safety of consumption and substantiality of irradiated foods have been studied extensively over many years by some leading international associations. The Joint FAO/IAEA/WHO Expert Committee on the Wholesomeness of Irradiated Food (JECFI) concluded in 1980 that the irradiation of any food commodity up to an overall average dose of 10 kGy presented no toxicological hazard and no special nutritional or microbiological problems [21]. In 1997, an FAO/IAEA/WHO Study Group on High Dose Irradiation concluded that food irradiated to any dose appropriate to achieve the intended technological objective is both safe to consume and nutritionally adequate [22].

The radiation dose is measured in SI units of Gray (Gy). 1 Gy of radiation dose is equal to 1 Joule of energy absorbed per unit Kg of food material. In the radiation processing of food, the doses are measured in terms of kGy (=1000 Gy) [20]. Based on radiation doses, application of radiation to food processing divided into 3 main categories as shown in Table 1:

TABLE I

Different Food Processing Applications with respect to their varying doses (Source: Radiation Processing of Food & Medical Products, A Technical Document, 2014)

Processes	Doses (kGy)
I. Low dose applications < 1kGy	
Sprout inhibition of tubers, bulbs, rhizomes	0.02 – 0.2 kGy
Delay in the ripening of fruits	0.2 – 1.0 kGy
Insect disinfestations of cereals, legumes, and their products	0.25 – 1.0 kGy
II. Medium dose applications (1-10 kGy)	
Shelf life improvement of meat, fish, fruits, and vegetables	1.0 – 3.0 kGy
Elimination of pathogens in various foods	1.0 – 7.0 kGy
Hygienisation of spices	6.0 – 14.0 kGy
III. High dose applications > 10 kGy	
Sterilization of packaged food and hospital diets	5.0 – 25.0 kGy

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In India, a Food Irradiation Processing Laboratory (FIPLY) was established in the Food Technological Division, Bhabha Atomic Research Centre (BARC) way back in 1967, where cobalt-60 gamma irradiation unit, called the Food Package Irradiator, was installed. But it was in 1994 when the Government of India authorized irradiation of potatoes, onions, and spices for internal market and consumption. Additional food items were added in 1998 and 2001. As per Food Safety and Standards (Food Product Packaging and Labelling) Regulations, 2011, the irradiated products are labelled and can be identified with the 'Radura' logo in a typical label. Presently there are only 14 Radiation Processing Plants operating in India [23].

India is yet to achieve success in curtailing the post-harvest losses and to provide quality food products for the internal and external markets. Food irradiation is one of the safest and efficient methods of food preservation ever developed which remains underutilized in India. This process can be utilized where conventional methods fail or pose serious health risks. Today, the needful expertise, know-how, and competent resources are available in India for setting up of more Radiation facilities. The consumer acceptance of irradiated foods is better. The enabling legislation is in place. Therefore, it is high time to do marketing of this technology, to establish a dialogue with the industry, farmers, cooperatives and corporations, consumer bodies to generate an integrated approach to fully utilize the commercial potential of food irradiation [24].

V. SOCIO-ECONOMIC STATUS OF INDIA

The practice of agriculture dates back to the Indus Valley Civilisation. India ranks second in crop production worldwide. As per 2018, 50% of the Indian work force was employed in the agriculture sector and contributed 15-18% of the country's GDP (Table II). As per current reports, the primary source of livelihood in India is agriculture for 58% of the population [25].

TABLE II

Distribution of gross domestic product (GDP) across economic sectors in India 2019 (Source: H. Plecher, Jul 28, 2020)

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
GDP (%)	17.03	17.19	16.85	17.15	16.79	16.17	16.36	16.36	15.41	15.96

Pre-independence India was struck by a large-scale famine in 1943, agriculture in India was stagnant, and the situation was firmly altered by the occurrence of the Green Revolution, by adopting various new approaches. The technological drawbacks have been widely overcome [26]. The main reason of food insecurity in India today is not just operational inability to produce more food, but also the failure to make the poor of the country able to afford enough food. The underlying causes of the hunger crisis in India are as follows:

1) *Poverty*: Poverty is persistent and is far from being eradicated. It is found that 23.6% of Indian population, or about 276 million people, lived below $1.25 per day. Poverty alone is not the cause of malnutrition, but it has an impact on the availability of nutrition to the most vulnerable populations.
2) *Natural causes of agricultural losses*: Natural calamities are responsible for losses in agriculture and consequently cause low harvest and undernourishment.
   a) *Acidity and salinity of soil*: Acidity and salinity are significant causes of losses in agriculture: 40% of irrigate area is affected by salt soil and 30% to 40 % of arable land is affected by acid soil which are responsible of 80% of yield lost.
   b) *Natural disasters and natural climatic oscillations*: Occurrences of natural disasters like droughts, cyclones, floods, etc. linked to climate change has increased substantially. Destruction of infrastructure; diseases are spread quickly; people can no longer grow crops or raise livestock.
   c) *Insects and diseases*: Insects are one of the biggest causes of losses in developing countries agriculture. Diseases like leaf rust and bacterial canker also are an important cause of agricultural losses [27].
3) *Diseases*: Diseases such as tuberculosis, measles, and diarrhoea are causative influences of acute malnutrition. A combination of illness and malnourishment weakens the metabolism creating a vicious cycle of sickness and malnutrition, leading to susceptibility to illness.
4) *Seasonal Migrations*: Seasonal migrations have long been a common practice of poorer households as a livelihood strategy. Children and women are worst affected, as they are deprived of proper health conditions and adequate diet. They reside in challenging conditions with unsafe drinking water, lack of sanitation facilities, no health care services and in make-shift tents [28].

VI. ETHICAL ISSUES RELATED TO GM CROPS

In the past few years, simultaneous research, development and commercialisation of GM crops has generated concerns regarding their potential impacts on the biodiversity, environment and eventually on the health of human beings and livestock. Concerns of Biosafety, environmental impact and ethical issues have major challenges for GM crops research and deregulation in entire world including India. Gene flow has become a more widely publicised issue in GM crops over the last decade. The transfer of genetic variation from one population to another is termed as gene flow. GM crops have the ability to affect the naturally occurring wild variant crop; they can even affect other GM crops grown in nearby fields. If a transgene is passed on to wild variety crops, they will get contaminated and then affect the gene pool. The issue of co-existence is a significant one to ensure that different kinds of crops can grow without harming each other [29].

Every country needs GM products to be approved before they may be grown in, consumed or imported into another country. India also has a bio-safety system in place. As the current law states, the commercial release of any GM product requires approval from the Genetic Engineering Approval Committee (GEAC). One of the crucial points to be considered in allowing genetically engineered or genetically modified crops is their safety for human beings and the environment. Besides the environment safety tests, the GEAC requires extensive food safety tests for the production of new GM products. The intervention of the government may also be executed in other ways for the GM crops.

In India, Ministry of Environment, Forest and Climate Change (MoEFCC) introduced the Environment (Protection) Act, 1986 as a framework legislation to provide protection and development of the environment. In relation with the use of micro-organisms and application of gene technology, the MoEFCC stated the "*Rules for manufacture, use/import/export & storage of hazardous microorganisms/genetically engineered organisms or cells, 1989*". Rules, 1989 are implemented by MoEFCC jointly with the Department of Biotechnology (DBT), Ministry of Science & Technology and state governments [30].

TABLE III

Six Competent Authorities for the regulation of ethics and their composition. (Source: V. Ahuja, "Regulation of emerging gene technologies in India", BMC Proceedings, vol. 12)

Advisory Committee	Roles & Responsibilities	Functioning under
1. RDAC rDNA Advisory Committee	Advise on Biosafety of emerging technologies	Department of Biotechnology, Ministry of Science and Technology
2. IBSC Institutional Biosafety Committee	R&D and Contained Experiments	Set up in registered institutions, Universities and Private Companies; report to RCGM
3. RCGM Review Committee on Genetic Manipulation	Scientific risk assessment of plants, animals, biopharma, microbes and guidelines	Department of Biotechnology, Ministry of Science and Technology
4. GEAC Genetic Engineering Appraisal Committee	Final Approval for environmental release including confined field trials	Ministry of Environment and Forests and climate change
5. SBCC State Biotechnology Coordination Committee	For monitoring and supervision at state level	Concerned State Authorities
6. DLC District Level Committee	Depending upon the need for local supervision and compliance	

VII. CONCLUSION

India is the world's largest producer of dairy, pulses and jute, and ranks as the second largest producer of paddy, wheat, sugarcane, groundnut, vegetables, fruits and cotton. It is also one of the leading producers of spices, fish, poultry, livestock and plantation crops which are sufficient to provide at least 4.3 pounds of food per person, per day. The Green Revolution in India stirred various technological advancements in the field of Agriculture and the livelihoods of a significant amount of the Indian population thrive on it. The most relevant underlying cause of hunger in India is poverty, and the ever-increasing population.

GM crops could help tackle this issue by providing surplus yields and being more immune to environmental stressors. Technologies such as food irradiation can also be adopted to increase the shelf life of these foods without compromising with their nutritional values.

Many biosafety issues related to GM crops have been addressed and studied by scientists and policy makers thoroughly since the release of first transgenic crop. These include effects on the ecosystem, gene flow, out-crossing, invasiveness, weediness, horizontal gene transfer, effect on non-target organisms, and evolution of virulent strains of pests and impact on soil. However, many issues are still a matter of debates because the potential long-term cumulative effects are yet to be studied. More than 100 million farmers in India are apprehensive about the fact that once GM crops become prevalent, their livelihoods and the nation's food supply will increasingly rely on expensive, rapidly changing and proprietary seed technologies owned by large private corporations. Thus, genetic engineering remains as a promising strategy to overcome India's food security crisis, scientists and policy-makers can collaboratively consider schemes to provide farmers with facilities and proper knowledge of GM crops so that the country's population as well as the farmers can benefit from it while simultaneously addressing the cardinal ethical issues that may arise.

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