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A REVIEW OF APPLICATIONS OF GENETICALLY MODIFIED (GM) CROPS FOR ECONOMICAL GROWTH

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ABSTRACT
Genetically modified crops or GM crops are obtained through the use of modern biotechnology, introducing new traits to the plant which doesn't occur naturally in the species. The application of GM crops in this developing world is of great benefits, which includes high crop yields, reduced farm costs, increase farm profits which lead to the economic growth of any country, safer environment, and availability of more nutritious food with greater food security and health benefits. This review article describes the methods used in the production of GM crops and their modifications, highlights the applications of GM crops for economical growth as well as for environmental and health benefits.

KEYWORDS: Genetically Modified (GM) crops, Agricultural biotechnology, Economical growth, Applications, Benefits.

INTRODUCTION
In the 21st century, biotechnology has been utilized as one of the eco-techno-political technologies available to fulfill the requirements of the growing population. Many countries have developed technological strategies to enhance their productivity in numerous fields. It is a widely held belief that applying those technologies could potentially contribute to the productivity of sustainable agriculture in ways which increase resource, poor farmers' income and ensure food security and safety.[8]

In agriculture, GM crops are the fastest adopted crop technology in recent history. The first GM plants-antibiotic resistant tobacco and petunia were successfully created in 1983 by three independent research groups. In 1990, China became the first country to commercialize GM tobacco for virus resistance. In 1994, the Flavr Savr tomato became the first ever Food and Drug Administration (FDA) approved GM plant for human consumption. This tomato was genetically modified by antisense technology to interfere with polygalacturonase enzyme production, consequently causing delayed ripening and resistance to root. Since then, several GM crops received approvals for large scale human production in 1995 and 1996. Initial FDA approved plants included corn/maize, cotton and potatoes (*Bacillus thuringiensis* (Bt) gene modification), Canola (Calgene: increased oil production), Cotton (Calgene: bromoxynil resistance) and Roundup Ready soybeans (Monsanto: glyphosate resistance).

Currently, the GM crop pipeline has expanded to produce other fruits, vegetables, and cereals such as lettuce, strawberries, eggplant, sugarcane, rice, wheat, carrots, etc. with planned uses to amplify the vaccine bioproduction, nutrients in animal feed as well as afford salinity and drought resistant traits for plant growth in unfavorable climates and environment.[5]

The largest review yet conducted concluded that the effects of GM crops on farming were overwhelmingly positive.[4] Now, GM crops are adopted by many developed and developing countries. Hence, the adoption and application of GM crops helps the country and the population in many ways such as for increasing economy of a country, providing food security and many more. The adoption of GM crops is also very much beneficial for several farmers of different countries. From the last few years, by the application of GM crops have leaded to a huge economic growth in many countries, which will be further discussed in this article.

METHODS AND MODIFICATIONS
In 1953, the molecular structure of DNA, the chemical carrier of genetic information, was published by (Watson and Crick 1953). Just over two decades later, Cohen et al. (1973) described the method with which functional foreign DNA could be inserted into another organism. This breakthrough became the basis of genetic modification, arguably one of the most important current developments in science, especially to modern agriculture. Thus far, genetic modification has primarily

been used to introduce foreign DNA into target crops to make them insect resistant or herbicide tolerant, with thesetwotraitsoftenbeing'stacked'.[3] GM crops are made through a process known as genetic engineering. Two supreme methods currently exist for introducing transgenes into plant genomes. The first method involves a device known as a 'gene gun'. The DNA to be introduced into the plant cells is coated onto tiny particles are then physically shot onto plant cells and incorporated into the genomic DNA of the recipient plant. The second method uses a bacterium to introduce the gene(s) of interest into the plant DNA.[1] Some other genetic engineering techniques are electroporation and microinjection. Electroporation is employed when the plant tissue does not contain cell walls. During this technique, DNA enters the plant cells through minute pores which are temporarily caused by electric pulses. Microinjection is employed to directly inject foreign DNA into cells.

GM crops contain novel genes (transgenes) with improved quality traits, such as herbicide tolerance, and allow the developmental process to be dramatically accelerated. GM crops contain novel genes (trangenes) with improved quality traits, such as herbicide tolerance, and allow the developmental process to be dramatically accelerated. GM crops are modified using three different ways of recombinant DNA technology, they are, transgenic, cisgenic, or intragenic. In transgenic modification the insertion of foreign DNA from an unrelated genus or species takes place. Cisgenic modification involves the insertion of one or more gene of similar species or from a crossable donor.

The introduction of specific alleles/genes present in the gene pool, without any DNA sequence change into new varieties is termed 'cisgenesis' and such processes accelerate the breeding of species with long reproduction cycles with no linkage drag. On the other hand, 'intragenic'modificationinvolvetheuseofgenetic elements from other plants from the same sexually compatible gene pool and, thus, the coding regions of genes are combined with promoters and terminators of different genes from the same sexually compatible gene pool.[2] Furthermore, there is a certain reluctance to accept GM foods created by transgenesis rather than cisgenesis, as the later process appears to be natural. Introduction of the R1 gene, which provides resistance to late blight of potato, from wild-type potato (*Solanum demissum*) to cultivated potato (*S.tuberosum*), is a cisgenic process. However, the transfer of the Bt gene from the bacterium *Bacillus thuringiensis* to the cotton genome to produces pest-resistant cotton is an example of transgenesis.[2] In 2002, Monsanto-Mahyco introduced Bollgard- I, India's first GM cotton hybrid containing *cry 1 AC* producing *Bacillus thuringiensis* (Bt) genes for controlling the pink Bollworm (*P. gossypiella*) pest.[5] Genetically modified crops are exploited to develop the desired quality traits, such as drought, temperature, or salinity tolerance or disease resistance.

Applications of GM crops for Economical Growth

The necessity for food due to an ever-expanding global population and changes in eating habits has consistently increased the demand for more productive food and feed crops. In fact, the provision of sufficient food to feed an estimated 9.7 billion people by 2050 and approximately 11.0 billion by 2100 is one of the major challenges of this century. The rapid adoption of GM crops within the agricultural sector has increased agricultural productivity, contributed food demand to met.[2] Genetically modified crops represent the most rapidly adopted technology in the history of agriculture, having now reached 25 years of commercial production. Grown by millions of farmers, many in developing countries, the technology is providing substantial economic and environmental benefits, such as depletion in chemical use of 37%, increased yields of 22% and improved farm profits of 68%.[7] According to ISAAA report (2017), about 67 countries adopted biotech crops, since 1996 (Figure 1). In 2019, (the 24th year of commercialization of GM crops) 190.4 million hectares of GM crops were grown by up to 17 million farmers in two countries. From the initial planting of 1.7 million hectares in 1996 when the first biotech crop was commercialized, the 2019 planting indicates ~112 fold increase. Thus, GM crops are considered as the rapidly adopted crop technology in the history of modern agriculture.[1]

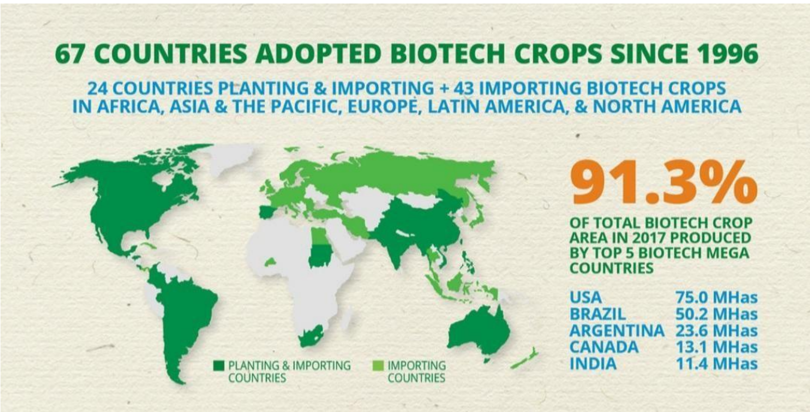

Figure 1: The figure depicts the global area of GM crops in millions of hectares 1996-2017. (Source: isaaa.kc, Flickr).

Some major GM crops which leads to the economic growth of a country are:

GM Cotton

In India, cotton has served as a crucial fibre and textile raw material and plays an important role in its industrial and agricultural economy. About 8 million of farmers, small and medium (having less than 15 acres of farm size and an average of 3-4 acres of cotton holdings) depend on this crop for their livelihood. Bt cotton's implementation has largely benefited Indian farmers and agricultural economy. Bt cotton has increased profits and yield by Rs.1877 per acre (US $38) and 126 kg/acre of farmland respectively. Bt cotton adoption has also resulted in a 22-fold increase in India's agri- biotech industry due to an unprecedented 212- fold rise in plantings from 2002-2011 (accounting for ~30% of global cotton farmland), exceeding China and making it a world leading grower and exporter. Cotton crop yields have also increased 31% while conversely insecticide usage has more than halved (46% to 21%) enhancing India's cotton income by US$11.9 bn.[5] Biotech cotton was planted to 25.7 million hectares, covering 79% of the global area of cotton in 2019.[1]

GM Canola

Canola in Australia is grown as a break crop, providing farmers a profitable alternative along with rotational benefits from continuous cereal crop phase and their related weed/pest mechanisms. It is most prominently grown in Western Australia (WA), where it accounts for 400-800,000 ha of farmland and is the most prosperous of four break crops (oat, lupin, canola and field pea). From 2002-2007, Canola production in WA alone accounted for a yield of 440 mn tones valued at A $200mn. In 2014, GM Canola planting area (hectares) was up to 14% in 2014 from just 4% in 2009, representing a near three-fold increase and contributing to Australia's growing biotech crop hectarage. This increase was more notable in WA, where GM canola was planted from 21% canola farmer in 2014, up from 0% in 2009.[5] Biotech canola occupied 10.1 million hectares in 2019, which was 27% of the total canola production worldwide.[1]

GM Soybean

Biotech soybean crop maintained its high adoption rate of 48% of the global biotech crops or 91.9 million hectares. This area was 74% of the total soybean production worldwide in 2019.[1]

GM Maize

Biotech maize enhaged 60.9 million hectares globally, which was 31% of the global maize production in 2019.[1] Aside from soybean, maize, cotton, and canola, many other GM crops were also planted in different countries which helps in the economic growth of a country, they are: alfalfa, sugar beets, biotech rice (golden rice), sugar cane, papaya, potatoes, eggplant (Bt Brinjal), squash, apple and pineapple. The most planted biotech crops in 2019 were soybean, maize, cotton, and canola (Figure 2).[1]

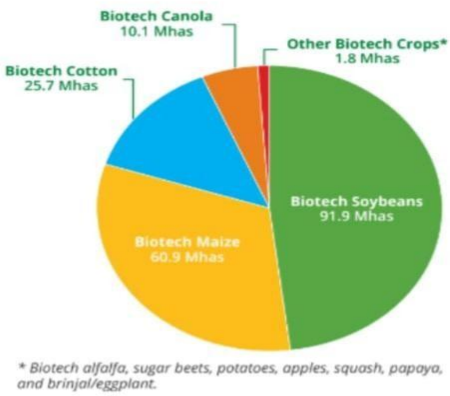

Figure 2: Biotech Crops in 2019 (Source: ISAAA, 2019).[1]

Applications of GM Crops for environmental benefits

Through several studies it was observed that, by the adoption of Bt cotton in China, across the entire sample region insecticide applications dropped from 14kg/ha to 4kg/ha. Similar environmental benefits from the adoption of Bt cotton in India were observed, where the Bt cotton reduced pesticide use by 41%. The rapid adoption of GM canola provided improved weed control options which reduced in one million tons of carbon being either sequestered by the soil or no longer released from implement passes. It was also proved that, CO_2 emission reductions equal to removing 10 million cars for 1 year.[6]

According to ISAAA, a study assessing the global economic and environmental impacts of biotech crops for the first 21 years of adoption showed that the technology has reduced pesticide spraying by 671.2 million kg and has reduced environmental trace associated with pesticide use by 18.4%. The technology has also significantly reduced the release of greenhouse gas emissions from agriculture equivalent to removing 16.75 million cars from the roads. According to the meta-analysis on the impacts of GM crops, GM technology has reduced chemical pesticide use by 37%. A study of US maize and soybean farmers from 1998 to 2011 concluded that adopters of herbicide tolerant maize used 1.2% (0.03kg/ha) less herbicide than non- adopters, and adopters of insect resistant maize used 11.2% (0.013kg/ha) less insecticide than non-adopters. Herbicide tolerant crops have facilitated the continuous expansion of conservation tillage, specifically no-till cultivation system in the USA. The adoption of conservation and no-till cultivation practices saved nearly 1 billion tons of soil per year.[1]

Applications of GM Crops for health benefits

GM crops, particularly Bt cotton, have resulted in substantial reductions in pesticide poisoning cases because of reduced applications and reduced levels of insecticide exposure. Basically, exposure to chemicals which results in the sickness of the person applying the chemicals is known as pesticide poisoning. Reductions in farmer pesticide poisonings are quantified in India, China, Pakistan, and South Africa. Often, cases of pesticide poisoning are not regularly reported to health centers and therefore the results on pesticide poisoning could also be underestimated because of the lack of reporting. In South Africa, farmers reduced pesticide usage from 11.2 annually to 3.8, with recorded cases of pesticide poisoning decreasing from over 50 annually to <10 over the initial 4 years of Bt cotton adoption. One third of farmers who doesn't adopted Bt cotton in China reported cases of pesticide poisoning compared with 9% of the farmers who adopted Bt cotton. Assessing the health impacts in India reveals a decline in cases of pesticide poisoning of 2.4-9 million cases annually. Farmers in Pakistan growing non-Bt cotton reported up to seven cases of pesticide poisoning in the growing season with 35% reporting no cases, versus Bt cotton farmers reporting up to six poisonings with 45% reporting none.[7] The amount of pesticide poisonings was reduced by between 2.4 million and 9 million cases a year.[6]

Mental health challenges and issues impacts all walks of life and economic sectors, including agriculture. Sadly, suicide is a concern in agriculture. India is in the peak in suicide cases in the world, and research has examined the relationship between farmer suicide and the adoption of GM cotton.[7] A research conducted in 2011 on the case of farmers committing suicide which reported a one-third reduction in the suicide rate following the release of Bt cotton among Indian farmers based on concluding and deducing the pre-Bt cotton commercialization suicide rate.[6] Farmer suicides were trending upward from 15,000 annually, peaking in 2004, the year after Bt cotton was 25% below the extrapolated suicide rate. Gradually, the reduced rate of suicide related to the adoption of suicide Bt cotton represents the prevention of a minimum of 75,000 farmer suicides.[7]

CONCLUSION

The advantage of GM crop applications has been reviewed in this article. It has analyzed that GM crops can hold substantial capability to contribute to poverty reduction, economic growth, environmental and health benefits. There has been a uniform increase within the number of hectares being planted to GM crops in the developing world. Millions of farmers manifest their trust in crop biotechnology by adopting GM crops in higher rate. This technology is very beneficial for small holder farmers. More efforts and practices for improving the GM crops can extend to better economic growth of a country and can fulfill the future food requirements of the growing population.

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