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IMPACT OF GENETIC ENGINEERING AND BIOTECHNOLOGY ON THE AGRICULTURAL SECTOR

Abstract: this article explores the profound influence of genetic engineering and biotechnology on agriculture, focusing on the advancements, challenges and future potential of this technological change. It highlights scientific innovations that revolutionized crop production, pest management and sustainability, aiming to address food security for growing population. However such application raises concerns about ethics, ecological impacts and quality of crop. Thus this article discusses potential risks and benefits of biotechnology emphasizing future trajectory of global food system.

Keywords: genetic engineering, biotechnology, food security, sustainability

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ВЛИЯНИЕ ГЕННОЙ ИНЖЕНЕРИИ И БИОТЕХНОЛОГИЙ НА СЕЛЬСКОХОЗЯЙСТВЕННЫЙ СЕКТОР

Аннотация: в этой статье исследуется глубокое влияние генной инженерии и биотехнологий на сельское хозяйство, особое внимание уделяется достижениям, проблемам и будущему потенциалу этих технологических изменений. В ней освещаются научные инновации, которые произвели революцию в растениеводстве, борьбе с вредителями и устойчивом развитии, направленные на обеспечение продовольственной безопасности растущего населения. Однако такое применение вызывает опасения по поводу этики, экологических последствий и качества урожая. Таким образом, в этой статье рассматриваются потенциальные риски и преимущества биотехнологии, подчеркивающие будущую траекторию развития мировой продовольственной системы.

Ключевые слова: генная инженерия, биотехнология, продовольственная безопасность, устойчивое развитие

Agriculture sector has historically been at forefront in developing human civilization. The global agricultural sector is under increasing pressure to meet the demands as we face growing global population to reach nearly 10 billion by 2050. Global productivity must increase by 60% to meet this demand, while minimizing environmental impact [7]. Imagine a world where farmers don’t have to rely on chemical pesticides to protect their crops, where rice can help prevent malnutrition and where plants can grow in harshest conditions. This isn’t a vision of a distant future – it’s happening now. . Genetic engineering and biotechnology have emerged as critical tools in addressing these challenges, enabling precise genetic modifications to improve crop performance and reduce reliance on chemical inputs. These technologies hold immense

promise for transforming traditional farming practices into more sustainable and efficient way.

How Genetic Engineering and Biotechnology Are Changing Agriculture?

1. Crops That Do More: Through genetic engineering, scientists are developing crops with superpowers. Bt cotton, for instance, increased yields by 24% while reducing pesticide use by 50% in India (ISAAA, 2020) [2]. Similarly, herbicide-tolerant soybeans simplify weed control and save farmers billions in labor costs globally.

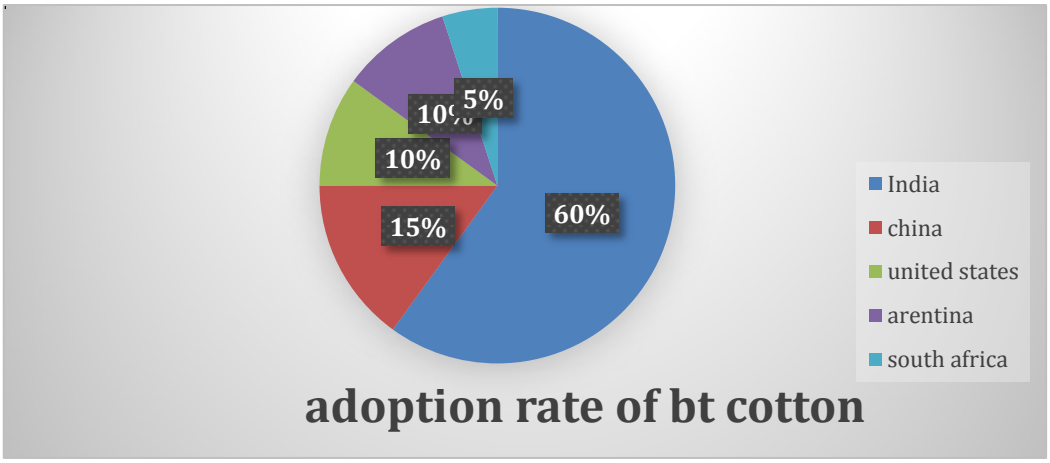

Figure 1 - Adoption rates of Bt cotton in major countries (2000–2020) (ISAAA briefs)

2. Fighting Hunger with Biofortified Foods:

Around 2 billion people suffer from micronutrient deficiencies (WHO, 2020). Golden rice, enriched with Vitamin A, has the potential to address this issue in regions like Southeast Asia, where rice is a staple. Studies show it could prevent up to 1.3 million child deaths annually [3].

3. Helping Crops Survive Tough Conditions:

As climate change intensifies, farmers are facing new and harsh realities, with droughts and floods threatening crops and livelihoods. In regions like Bangladesh, where rising sea levels have made soil saltier, traditional rice varieties struggle to survive. But there's hope: salt-tolerant rice is proving to be a game-changer. Farmers in affected areas have seen their yields increase by an impressive 25%, offering not just

more food on the table but also renewed resilience against an unpredictable future [4]. It's a powerful reminder of how innovation can adapt to nature's toughest challenges.

4. Reducing Waste and Protecting the Planet:

Genetic engineering is also playing a role in reducing food waste, which is a huge global issue. Take slow-ripening tomatoes, for example. These genetically engineered tomatoes stay fresh longer, meaning fewer are spoiled during transport and wasted before they reach consumers. On a larger scale, biotech crops are helping reduce the environmental impact of farming. In 2020, they helped cut carbon emissions by an impressive 23 million metric tons—like taking millions of cars off the road for a year [5]. It's a reminder that technology not only helps feed the world but also makes the planet a little healthier.

Challenges we need to address

Imagine a small farmer standing in the middle of a vast field, his eyes scanning the horizon. The future of agriculture, filled with technological innovations, is right before him, but with it comes a bundle of challenges that demand attention.

1. What About the Environment?

While genetically engineered crops offer promise boosting yields and reducing pesticide use they bring some unexpected guests. One of the most pressing issues is herbicide-resistant weeds. These resilient plants are spreading across the globe, now affecting over 249 species (Weed Science Society, 2020), and they're making life harder for farmers who rely on herbicides to keep their fields clean [6]. For the farmer, this means the need for even stronger chemicals thus potentially creating a never ending battle between technology and nature. It's a tough call: can we push innovation forward without tipping the balance of the environment?

2. Can Everyone Afford It?

Now, imagine the farmer is joined by his neighbor, a smallholder whose farm barely covers his costs. For farmers like him, the dream of using genetically modified

seeds remains out of reach. These seeds can be up to 30% more expensive than traditional ones, which creates a major roadblock [1]. In many parts of the world, including rural regions, the cost of these patented seeds means the benefits of biotechnology are often reserved for those who can afford them, leaving smaller farmers to wonder if they'll ever get a fair chance to benefit from these innovations.

3. Protecting Diversity

Walking through his fields, the farmer also wonders about the long-term effects of growing the same genetically modified crops year after year. Large-scale monoculture farming may boost short-term profits, but it weakens the gene pool, making crops more vulnerable to pests and diseases. As technology grows more powerful, preserving genetic diversity becomes crucial to safeguard agriculture against unforeseen challenges. Perhaps it's time to look back at traditional farming methods, which may hold the key to a more balanced and resilient agricultural system.

4. Ethical issue? OR Trust issue? Do we fully trust it?

As the farmer walks to town to sell his crops, he hears the buzz of skepticism around him. "Are GMOs really safe?" people ask. In Europe, 39% of consumers avoid genetically modified foods due to health concerns (Eurobarometer, 2022) [7] . The farmer, despite having seen the success of these crops firsthand, knows that consumer trust isn't just built by technology it's built by transparency. In Russia, there is strong public resistance to GMOs, influenced by fears of long-term health impacts and distrust in multinational seed companies Clear labeling, better communication, and more open dialogue about the science behind GMOs could help ease public anxiety and change minds. After all, even the best technology needs a good story to be fully embraced.

What's next?

The future of farming is on the brink of an exciting transformation. With the world's population growing rapidly, and environmental pressures mounting, agriculture is turning to more precise, powerful tools—tools like CRISPR, the revolutionary gene-

editing technology that allows scientists to make minute, targeted changes to an organism's DNA. Think of it as a digital scalpel for genes, allowing crops to be engineered with greater precision than ever before. This means we can now solve problems like drought resistance or pest control with an accuracy that’s more effective and less wasteful than previous methods.

And this is just the beginning as

- By 2030, precision gene-editing technologies are expected to expand to 70% of biotech crop development (OECD, 2022) [8].
- Global GM crop acreage, currently at 190 million hectares, is projected to surpass 250 million hectares by 2035 [2] (ISAAA, 2021).

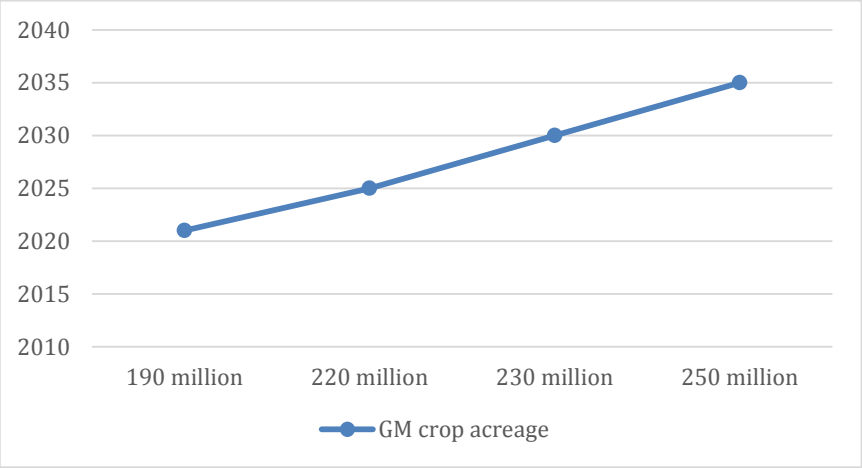

Figure 2 - Projected growth of GM crop acreage ISAAA 2021 [2]

Genetic engineering and biotechnology are rewriting the future of agriculture. They have the potential to feed the world’s growing population, reduce environmental impacts, and make farming more resilient to climate change. However, ensuring these benefits reach everyone from large-scale industrial farms to smallholders in developing countries will require thoughtful policies and collaboration.

The journey ahead is both promising and challenging, but one thing is clear: genetic engineering and biotechnology are shaping the future of food in ways we could only imagine few decades ago.

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