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Emerging trends in agricultural biotechnology: An Indian Perspective

T. P. Rajendran*

Abstract: The significance of advancements in biotechnology research was captured in the deliberations at the FAO International Symposium, held in February, 2016. The futurism that resonated from the showcasing of a number of products from the research on agricultural biotechnology was the highlight. The side-shows addressed the contemporary global benefits from agricultural biotechnology and the potential for harnessing those on scale through prudent policy approaches and fine-tuning of farmers' practices to adjust the outcome of research on agricultural biotechnology. The contrasting views on the benevolence from agricultural biotechnology vis-a-vis improvement in utilization of farm resource efficiency did stir introspective deliberations. The socio-economic assessment of such products under different national contexts may reinforce the faith and confidence of agri-biotechnology products for farmers and consumers alike. The Indian perspective on the agricultural biotechnology for preparing the country's agricultural state towards better preparedness for future abiotic stress challenges from global climate changes, economic growth in trade and commerce of both the commodities and input supply chain is discussed.

Key words: agricultural biotechnology, small farm challenges, socio-economic assessment, biofortified crops, climate resilient crops, animal biotechnology, diagnostics and vaccines.

Introduction

The fascinating fusion of futurism of the state of knowledge and developments in agricultural biotechnology was unfolded in the FAO international symposium, held in February, 2016 'on the role of agricultural biotechnologies in sustained food systems and nutrition'. The thoughts that reverberated were to deploy the modern molecular breeding tools along

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* Visiting Fellow, RIS, E mail: tp.rajendran@ris.org.in

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with biotechnology to combat perceived challenges from climate change and such other global geological challenges. The quest for improving crop varieties and animal breeds for enhancing uninterrupted productivity and sustained profitability has been globally ongoing. Aspiration for food and nutritional security did make nations seek headway in increasing higher threshold of scientific knowledge and resultant technology on enhancing genetic variability of desirable trait (s) better higher nutrition through commodities (FAO, 2016). National investments encourage such R & D in addition to placing regulatory infrastructure complemented with enabling laws (Spielman 2016; Hegde 2016)

Overview of the FAO Symposium

The International Rice Research Institute gave an overview of research for rice crop to sustain submergence, drought and salinity in tropical coastal South Asian deltas through quantitative trait loci (QTL)-based genes to develop tolerant rice varieties to face climate-change driven situation in agricultural farms. The Chinese research report on the development of Great Super Rice (GSR) with pyramided genes through genomic design, traditional selection and marker assisted selection process for improving 'use-efficiency' of water, nutrients and with pest resistance without any genetic modifications has been major biotechnological achievement. Farmers in South Asia and Africa could benefit from the GSR. The crop improvement of Bambara groundnut, one of the African orphan crop, shall bring about African nutritional security by bringing this vegetable crop to higher productivity levels under low farm resource and management. Shelf-life enhancement of fruits and vegetables through biotechnology interventions was discussed. By precisely altering the nucleotide sequence of ethylene gene, the storability and transportation of fruits such as melon and tomato has become possible.

The International Wheat and Maize Improvement Centre (CIMMYT) outlined the research for water efficient maize (WEMA) for Africa. WEMA countries are Kenya, Uganda, United Republic of Tanzania and South Africa and have incorporated Bt genes in maize for resistance from borers. Utilising genomic technologies, wild chickpea germplasm collections have been characterized for genomic assemblies have been produced. In a global programme led by University of California, Davis,fitness of forest species was studied in forest trees to understand the response of forest tree species to climate change scenario. Genome assemblies of cultivated and wild chickpea genetic materials have been achieved. These are utilised to identify trait-marker association and deployed for crop improvement using marker-assisted selection process. Microbial community analysis of chickpea root zone has through light on the strategies to combat disease problems and drought tolerance in the crop.

Enhancing grain nutrition in rice and wheat has been the agenda in the crop improvement strategies for many decades. However, good the genetically modified rice and wheat varieties with genes from alien sources may be, their consumer acceptability is tougher than mixing various source foods on the plate to attain the purpose of supplying wholesome nutrition. Biofortified rice, wheat, sweet potato, etc. have promise to challenged populations for basic nutrition.

The AdapTree project of western Canada (University of British Colombia) studied the single nucleotide polymorphisms associated with climatic variables for about 23,000 genes as well as non-coding regions for hundreds of populations of pines species were identified to apply in assisted gene flow from warm areas to cold areas for warm-adapted pines. Delivery of new technologies that aid in managing climate change-directed farm ecologies was discussed. Tree genetic resources for livelihood, food, fuel, construction, fodder, medicines and many other purposes and are managed in some form of the commons, on public land, or in community forests. Improvement of Eucalyptus pulp yield, improvement of *Allanbackia*trees for their oil content in Africa and such other programms have sought solutions from biotechnology and molecular science. Utilising atoxigenic *Aspergillus flavus* strain (AflaSafe) for suppressing the toxigenic same fungal species, there is great hope for small holder farmers to utilise the technology in containing the aflatoxin in maize and groundnut of African and Asian countries.

Animal Biotechnology

In the Animal biotechnology sector, cost-effective production of vaccines, sexual selection of poultry eggs, mobilizing microbial genes to degrade lignin and cellulose in the gut of livestock animals so as to reduce unwanted methane emission, especially from ruminants were the sectoral interests that were elicited by the participating countries/speakers. Single nucleotide polymorphism (SNP) markers were used to improve dairy cattle. SNPs were used to identify genetic basis to African swine fever. Genetic basis for fecundity in goats using the highly fecund West African population was worked out in goats from diverse and marginal environment of West Africa. Challenges in application of biotechnology for animal breed improvement are the high cost of genomic tools/marker assisted systems and absence of phenotypes in small holder systems for assessment of performance for genome determination.

Developments in animal nutrition to improve metabolic efficiency and increased tolerance to biotic and abiotic stresses in farms have been fascinating. The deployment of pre-biotics such as non-digestible bio-active molecules for selective growth of certain flora in gastro-intestinal environment, to digest, assimilate and absorb critical nutrients from the food that are consumed. Similarly, use of probiotics, enzymes, yeast-embedded micronutrients, fermentation-based amino acid supply, etc. is useful in poultry and piggery.

Diagnostic tools to detect tuberculosis pathogen in dairy products to reduce chances of movement of the pathogens from animals to humans has been success story in Brazil. Nested PCR technique innovated the quick diagnostics technology unlike the very labyrinthine culture methods well replacing the intradermal tuberculin test for bovine tuberculosis.

Application of Gene-modification technologies in fisheries has been attempted in aquaculture organisms and has not so far found any commercial success due to various limitations. Gene banking in fish is currently possible for sperms. Assessing cryopreservation of sperms for gene-banking to assess the performance of breeding programmes is good tool. However, cryopreservation has not found large-scale application in routine seed production. Cryopreservation of eggs and/or embryos is serious limitation. Negative impressions on the genetic modification in fishes for consumption hampered the early success in China in 1980. AquaBounty got US Food and Drug Administration's approval for the long-running effort for Atlantic salmon with modified growth hormone expression. With huge regulatory cost and protocols of experimental maintenance of test fish populations, this simple GM fish technology by micro-injecting many copies of the target DNA into the fertilized eggs is under validation. However,the sharpening of tools on gene editing from such experience could be the future bet for more accurate genetic modifications in fishes. Improvement of resource use efficiency in fisheries can be anticipated through applications of biotechnology tools. Yet another interest in the fisheries genomics is used to study the structure of wild populations of many aquatic species using polymorphic DNA markers such as microsatellites and single nucleotide polymorphism etc.; for parentage assignment in mass-spawning species and to allow communal rearing of families in breeding programmes so as to reduce environmental effects on the selected traits.

Feed additives from microbial processes and phytases are handy in culture fisheries to enhance nutritional quality of fishery organisms. The commercially formulated and produced aquaculture feeds of about 42 million tonnes globally have microbial derived dietary essential amino acids, dietary enzymes, yeast-derived micronutrients, nucleotides and immune enhancers. Fish as food source has been dependably considered to be healthier over other animal protein sources. FAO report (2010) based on the joint consultation of FAO / WHO experts on the risks and benefits of fish consumption has emphasized on the benefits of this food types for sustaining human health.

Regulations and IP protection

The release of crop biotech products for cultivation is regulated by the sovereign national laws and rules thereon. Transgenic crop plants, Living modified organisms (LMOs) as well as animal biotech products come under regulatory regime. These innovations leading to various technologies come under the intellectual property rights. Intellectual property protection in recent decades has called for globalised harmonization and strengthening in agricultural research and development. The surge in such IP protection brought about increasing innovations in the field of agro-chemical research. Agricultural biotechnologies are within the framework of technology transfer. Permissive licensing of IP rights can infuse these technologies for adoption by farms. Diffusion of technologies through benevolent licensing ‘open-access’ framework, prior informed consent (PIC) associated with access and benefit sharing of genetic resources, could be the plan for the future of IP rights of the genes in play for crop/animal improvement for creating better commodities for trade (Sara 2016; Glover 2016; Chaturvedi 2016).

The time taken for perfecting the innovation into benevolent technology and that for attaining regulatory approval in any country takes about two decades. So today's farmers may not enjoy the fruits of such path-breaking R&D that would mature into approved technologies after two decades from now. The discourse on human perceptions on risks associated with such products in influencing agri-biodiversity and to human and associated animal health is long-drawn. Investments in biotechnology solutions through capacity development and partnerships were emphasized. However, these partnerships are in islands of initiatives. The South-South collaboration in agricultural biotechnology exemplified the connectivity under IBSA and BRICS groups is significantly noted (Chaturvedi and Srinivas 2016).

The collaboration between India and Bangladesh in GM Brinjal with delta endotoxin expressing gene of Bt. is a bilateral biosafety management approach for capacity enhancement. Recently initiatives from UNEP has brought about better mechanistic for perceived risk assessment and mitigation from LMOs. However, sovereign nations need to appreciate and enact laws that would enable the regulatory process for approval of the specific biotechnology product (s). Often such risk analysis predominate political discourses and even the scope to legitimise estimates through socio-economic analysis on the various impacting factors become mired into various conflicts of interests.

Socio-economic assessment

Socio-economic (SE) impact assessment for biotech products can provide definitive picture about the anticipatory hazards and risks posed to existing farm agronomy, farm resources, farm economy, ongoing traditional agricultural practices, farm income, farm profitability, well-being/health, and other contextual social issues. Ex-ante and ex-post analysis of SE concerns need to be the precursor for evaluating the robustness and benevolence of biotechnology and the derived products out of that. The biotechnology product-generating research shall be interested to invest in the SE analysis of the product that is ready for necessary statutory clearance in any country. The FAO conference did dedicate a session for signifying the importance of SE assessment studies of GM products. The recommendations from the three parallel sessions on (a) social and economic impacts of agricultural biotechnologies for small holders, (b) public policies, strategies and regulations in agricultural biotechnology and (c) investing in biotechnology solutions through capacity developments and partnerships.

The SE analysis GM biotech products has not been seemingly significant. The penchant for significant awareness of risks of the GM biotech products did gave a bias towards such studies *vis-à-vis* those of other biotech streams such as biofertilisers and biopesticides as well as on the advancements in animal biotechnology, particularly in karyotyping of local breeds, use of embryos for bull production, cloning of elite breeds, thermostable vaccines, recycling of dung and other livestock wastes, food and nutrition management to limit methane gas emission etc.

The deliberation derived rich discussions on these themes and enabled the following output (Chaturvedi 2016).

- Political commitment of nations to improve the efficiency and encouragement to the livelihood of small holding farmers;
- Suggestions for enabling financial support, partnerships, investments for human capital and infrastructure for Science and Technology and development of markets;Recognizing and nurturing the preservation and utilization of traditional knowledge of every nation;
- Developing a glossary of universalized definitions and vocabulary of terminologies in agricultural biotechnology;
- Recognition of the historical evolution of biological and engineering science that are integrated into agricultural biotechnology would clarify intended and un intended perspectives of the GMO products and their hazards and benefits for open evaluation of benevolence;
- Emphasis on institutional and national responsibility to transcribe the sky-rocketing scientific advancements in agricultural biotechnology to the common public at large and the farmers in particular with a built up responsibility;
- National R&D agenda and plans with policies to assess and calibrate the instruments on access and sharing of agricultural biotechnology knowledge for every agricultural production system along with stake-holders involvement for decisions;
- Dynamic policy choices for public-private partnerships towards utilizing the benefit of advancements of agricultural biotechnology knowledge;

- Open source tools and expertise to reduce costs in development of agricultural biotechnology solutions to solve threats from climate change in agriculture may be accepted as global convention; and
- Mega-mergers in biotechnology business enterprises to enable global philanthropic good of agricultural biotechnology R&D outcomes;

It appears that the derivatives of this Session did not, however, touch upon the impact of intellectual property rights and the various articles of the UPOV and CBD conventions in regard to securing famers' rights (FR) as well as on the risk mitigation liability of the technology originator and/or their rightful legally authorized agents. In recent discourses on the challenge to FR for LMOs including of genetically modified crops, the significant issue has been on the need for respecting FR once the farmers adopt the technology. The sustained campaign to make the farmers to adopt the GM crop seed shall be in order to improve the marketing strategy without due diligence on the stewardship of their seeds towards any agronomic or other forms of failure. The seed companies who popularize their GM crop planting materials do not show adequate responsibility towards the mitigation of emerging risks on the failure of technology under a given agro-climatic situation and the agronomic non-performance as also the difficulties of marketing the GM commodity.

Contemporary Developments

The five side shows on contemporary issues and matters of relevance to global agriculture, food and nutrition enriched the symposium output. The focal point on the need for practical approaches for regulations and oversight of agricultural biotechnology pumped in the concepts on (i) public acceptance on the safety and risk assessment of agricultural commodities from agricultural biotechnology-mediated commodities; (ii) enhanced scope for capacity building for both regulatory management and confident decision making; (iii) effective resolution of ownership and intellectual property issues and (iv) regional cooperation in sharing of resources, experience, infrastructure that enable global agricultural commodity trade. The side-show was sponsored by the Governments of Canada and United States of America.

New crop breeding technologies for Small-holders' challenges shall become part of the tool-box for sustained endurance of vagaries of weather, degrading quality of air, soil and water, improving commodity quality for better nutrition, shelf-life, tolerance to key biotic and abiotic stresses in crops. The Ministry of Economic Affairs, Government of Netherlands sponsored this show with the emphasis on countering possible constraints out of the intellectual property rights and biosafety rules upon the new breeding techniques and seeds. Canadian Canola Growers Association prompted to seek attention in identifying agricultural biotechnology as integrated practice of farmers' ongoing farming practices through a side-show that highlighted the benefits as well as limitations of the products from biotechnology research globally. Empowering farmers to choose the biotechnology products that fit into their farming practices is essential to help farmers grow in the environment of challenges posed by climate change technology nexus and food security call was showcased by CropLife International. The consortium of public private partnership institutions in South Africa highlighted the joint efforts to successfully launch the 'Africa biofortified sorghum' to deliver nutrition, productivity and climate resilience.

The conference enabled two contrasting ideologies on the benevolence of biotechnology and its products. The first session had statements from protagonists of biotechnology glorifying the human benevolence in agriculture from this modern biological science. The Brazilian delegation put up the view on the advantages that Brazil could reap in reducing nitrogen use in crops by increasing the use of crop-specific biofertilisers, as biotech products to the extent of up to 50 per cent of cultivated area for crop nitrogen requirement in soyabean, maize and , saving farmers' expenditure by about US $5 billion during every season. Similar approach in maize and pulses are in progress. Animal cloning, breed improvement and vaccines changed the complexion of their meet industry. Bioeconomy activities from biorefinery and biomass-technologies are pursued for sustainable energy so as to enable creation of new jobs in rural areas. A contrasting view was spun by Prof. Gunter Pauli (Zero Emission Research Initiative Network – ZERIN, Japan) whose protagonism on re-engineering resource productivity as a paradigm of agricultural productivity and growth reverberated and reflected on the human benevolence of innovations in agriculture due to advancement of science. Prof. Pauli (2016) spoke about the cost-burden on small farms to access and reap benefit from new agricultural technologies that do not have location specific crop production practices. 'In the global business environment, as for the example of crop seeds, the net price that farmers are charged for hybrid seeds is higher than that of the local crop seeds', was what Prof. Pauli felt as the 'technology driven subjugation.

The Director General, FAO stated at the commencement of the Symposium, 'we cannot lose sight of the fact that biotechnology knowledge and innovation must be available, accessible and appreciable to family farmers. Otherwise they will have limited impact'. The aspirations for common good and achieving development of rural masses through the adoption of new agricultural biotechnology solutions is not fully achieved due to the business model adopted by corporate companies who developed such technologies with their commercial investment interests. If the governments have to seek public benevolence to its agricultural sector these agricultural biotechnologies have to be subsidized to farmers. Various routes adopted for this purpose by governments such as negotiating the IP status and value of technology with the companies, providing subsidy to seed and other essential input cost developing suitable instruments to encourage such technology developers to provide necessary on-farm support to produce profitable crop commodities. In the scenario of uncertainties due to the impact of climate observations and requirements of sustained food and nutrition supply to the world and keeping global policies on zero hunger and towards achieving developmental goals the discussion in the symposium were to provide useful views.

Brazil is a nation that has become the globally second largest user of GM crops (Lopes and Machado 2016) in 42 m ha in 2014-15. Currently the research for innovation in agriculture biotechnology for GM crops has resulted in 45 events in corn (25), cotton (12), soybean (6), dry edible beans (1) and eucalyptus (1). Herbicide-tolerant GM crops has been under cultivation in 65 per cent of the total planted area and the rest with insect resistance GM crops. Soybean, corn and cotton are the crops that drive the Brazilian economic growth. The Brazilian model (2015-16) for agricultural biotechnology R & D adopted in developing GM bean variety, "Cultvance", under EMBRAPA for resistance to golden mosaic virus disease along with herbicide tolerance. This has been deregulated and in a joint venture with German multinational company – BASF would be used for commercial cultivation. Other GM crops research in passion fruit, sugarcane, cowpea and eucalyptus have advanced after the enactment of the Biosafety law, 2005 that fortified the investors' confidence in Brazil's agribusiness.

New cattle breed development to weather the topical climate changes using genomics is advancing. Being global player in meat trade, Brazil has invested in agricultural biotechnology for the sustained production of high quality meat. The reforms in sanitary and phytosanitary protocols for animal production-management systems have enabled the country to attain superlative trade advantages.

Developing the super-efficient nitrogen fixing Rhizobia bacterial strains that have been developed through agricultural biotechnology research and introduced in non-legume crops such as soybean, sugarcane and corn along with legume crops. This technology has reduced the dependence of nitrogenous fertilisers in 30 m ha soybean farms, saving about US $ 5 m to the nation on hydrocarbon-derived fertilisers.

Industrial level production of micropropagated clones of eucalyptus and pine has enabled the country to enlarge their cultivated area. Novel biotech formulations of microbial preparations for biological control of various biotic stresses in crops became a boon to farmers to reduce dependence on chemical synthetic pesticides.

Nascent boost in Brazilian investment is fully agricultural-centric to exploit metabolic processes of organisms (plants animals and microbes) for producing high value products for chemical, biochemical, medical, pharmaceutical, nutritional and energy industries. Sustainable energy supply from biomass/biorefinery technologies are primary thrust of the country for creating multiple opportunities for economic growth and creation of new jobs in rural areas. Heavy investments in the R & D seek technological progress in several fronts to scale the mounting national challenges. Integrating biotechnology R&D with the advanced sensors/instrumentation, automation, robotics, communication, nanotechnology has been the way of Brazilian planning to achieve durable growth in agricultural sector in the near future.

Indeed the Brazilian experience of pursuing agricultural biotechnology towards innovations for advancing agricultural growth has been noticed by the developing world and has caught up the attention of funding agencies. But as Prof. Gunter Pauli expressed about the need for sustainable agricultural production plan, the over-reliance on disruptive technologies that can damage natural cycles of replenishment of the lost biological entities that support uninterrupted agricultural processes in farms need to be emphasized (Pauli 2016.) How best socio-economic perspectives of modern biological innovations and developments in biotechnology could secure the stability and sustainability of natural processes and utilise the scientific advancements for higher growth and development of agricultural sector need country-specific debate and deliberations for creating informed choice.

Indian Scenario

Seen in this context, a relook at developments in biotechnology policy in India is necessary. From 1980s, the launch of biotechnology research in various Indian public institutions commenced mainly on cell-lines, tissue culture, rDNA techniques for animal vaccines, disease diagnostic kits, etc. However, in the context of the launch of products such as GM cotton in India the arguments on the veracity of claim as the best bet for the intended trait value had increasingly risen as intellectual discourse amongst biologist and subsequently amongst social scientists. Unfortunately, the reflections and reverberations of these deliberations began as narrative only since 2005. The 'social codes' (Janaki and Reddy 2005) in agricultural biotechnology development undertaken in any part of the globe needs appropriate and country-sensitive accounting towards the scope of global spread of the technologies. The labyrinthine regulatory process hampering original Indian innovators from getting supported by adequate institutional logistics to undertake the regulatory processes has indeed catapulted into the decelerated discoveries of agri-biotechnolgical products that have gene-modifications for trait improvement (Damodaran 2004). The research for improvement of nitrogen fixing microbial (Rhizobia, Azotobacter, Blue green algae, etc.) strains, improvement of fungal antagonism efficiency, vaccines for animal diseases and diagnostic kits for animal (including fishery) as well as plant diseases and many others that have huge economic and commercial benefits to farmers and the country are not reaching the end of the tunnel for utilization by farmers. The exercising of intellectual property rights of the agricultural biotechnology products having the basic knowledge domain for enhancement of trait value (s) has, over a period of time, resulted in the phenomenal escalation of costs of crop seeds in trade. The affordability of the inventions in agricultural biotechnology that claim for farmers' benevolence should have been under consideration when business models are developed to market the products from them (Lalitha 2004). The debate on the affordability of costs of products from research on agricultural biotechnology to the majority of farming community in India is strife with the issue of the present trends to marginalize such community due to deprivation of access to technologically fortified seeds and also to reduce the agri-biodiversity of conventional farmers' varieties of crops in Indian farm lands that have improved trait values out of biotechnology research. The argument that the national agri-GDP growth is to be technology-driven shall examine the growth in productivity from higher farm-land area over growth through high value technologies that are restricted (due to high cost of seeds) in land area. This assumes more significance especially when the technology-fortified crop species are to be cultivated within the limits of permissible agro-ecologies and productivity is guided by prevailing agro-climatic interactions with the crop variety genes. The total factor farm productivity of GM trait-bearing crops has to be assessed over that from the non-GM crop variety of the same crop over a decade or beyond to establish the worthiness of such new technologies in agriculture. Interesting developments in animal disease vaccines and diagnostic kits of animal diseases have been possible in India due to steadfast and continuous funding for their research and innovations by the Department of Biotechnology. The native biotechnology products in animal diagnostics and therapeutics including vaccines have made the cost of animal husbandry much low.

Another emerging dimension is to weigh upon the national benefit assessment due to introduction of such agricultural biotechnology products. The-agricultural commodities from GM crops end up as industrial raw materials as in the case of cotton fibre mainly in textile industry, cotton seeds in vegetable oil industry, feed industry etc. in India. The socio-economic analysis on GM crops and their commodities may have to examine the demand posed by the GM technology in altering the technical specifications of the industrial raw materials, calling for changes in the industrial processes and/or machinery. Such measures of uncertainties need to be weighed upon for evaluating the true benefits of new agricultural biotechnologies. The look up to comparison between investments and outcome of true economic benefits from agricultural biotechnologies needs to be based on available tools as well as newly designed and customized tools and techniques. This situation demands for the setting up of new indicators and criteria of socio-economic assessment of pipeline agriculture biotechnologies that are for commercialisation.

The SE analysis of the non-GM products from biotechnology innovations such as strains of biofertiliser or biopesticides, or other biotech products from animal biotechnology may add better confidence level to their consumers in agricultural farms to deploy them in various crop husbandry plans during each season. Relentless on-farm stewardship can diffuse the biotechnology products in Indian agricultural farms along with their continued availability as 'farm input service' even in remote villages. The government and civil society establishments may encourage suitable agencies to undertake SE analysis of the potential biotechnology products before being launched. Along with the mandatory biosafety studies of such biotechnology products, worthwhile confidence building SE analysis could enable better technology adoption and stimulate higher agriculture growth.

Thus the core question 'where the agricultural biotechnology can lead us' is answerable within the framework of access to large majority of Indian farmers at affordable price as well as on the long-term performance of such traits and products in the varying agro-climate of the country in the presently turbulent period of drastic weather patterns.

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