LKS | In Focus

FARM TO FOOD: KEY TRENDS AND REGULATORY OUTLOOK IN AGRITECH

POLICY

4. Seed industry: An overall perspective

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Seed industry: An overall perspective

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Introduction

Agriculture is the primary source of livelihood for about 58% of India's population. Gross Value Added (GVA) by agriculture, forestry and fishing was estimated at INR 19.48 trillion (US$ 276.37 billion (bn)) in 2020 and growth in GVA for the sector stands at 4% this year.[1] In light of the above and acknowledging the pivotal role played by agriculture in the Indian economy, sustainable agriculture, in terms of food security, rural employment and environmentally sustainable technologies such as soil conservation, sustainable natural resource management and biodiversity protection, has been deemed essential for holistic rural development.[2]

That being so, the need for innovation and digitisation in the agriculture sector rose once we got higher on the Jungian pyramid in farming. Now, there is also a need for a shift from a production-centric approach to a farmer's individual income-centric approach.

To reach these goals, historically, Indian agriculture and allied activities have witnessed a green revolution (food grain production), a white revolution (milk), a yellow revolution (oilseeds) and a blue revolution (fish). That being so, the need for innovation and digitisation in the agriculture sector rose once we got higher on the Jungian pyramid in farming. Now, there is also a need for a shift from a production-centric approach to a farmer's individual income-centric approach.

"We need to take a step away from the Green Revolution, or the White Revolution that refers to milk and talk of an "income revolution" that is able to capture the entire value chain right from research up to the stage where the farmers are able to realize money in their pockets." said Mr. Ashok Dalwai.[3]

Accordingly, what is the need of the hour is a shift from production-centric infrastructure to market-centric infrastructure and giving market access to all the farmers, particularly smallholding farmers. What is required is moving away from business-as-usual and towards market orientation for agriculture, i.e., from agriculture as a welfare sector, to a business sector.[4] This establishes the exact intent behind introduction of technology in agriculture and how it benefits or affects the various stakeholders of the sector, including seed manufacturing companies and corporates in this arena.

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The need of the hour is a shift from production-centric agricultural practices to market-centric agricultural practices and giving market access to all the farmers, particularly smallholding farmers.

External factors such as erratic climatic conditions, lack of infrastructure, awareness, etc., contribute to the lack of desired yields. Technological innovation, knowledge transfer at grass root levels, and leveraging the digital medium for real time solutions can transform the sector and make it overcome most of the difficulties.

The Central Government has been highly proactive with its legislations and is constantly pushing to reform the sector, which requires not only active support from the State Governments but the farming community too.

Traditionally, it has been a struggle between farmers' rights and the breeder / innovation rights of private corporations in the agriculture sector. The laws made and to be made should not fail to recognise and acknowledge the rights of innovative farmers in bringing new varieties and breeds.

Exports of Indian seeds and the foreign investments flowing into India can also be adversely impacted, if not climate conditions persist and its ill effects are neutralized, if not reversed.

India has a huge potential for becoming an export capital of seeds and agricultural products. However, there has to be much policy enablement and the requisite infrastructure to support the cause.

For any system to thrive, it should accommodate the competing interests of the stakeholders. Indian government is pushing for an increase in the pace of innovation. One such idea is the public-private collaboration for exchange of information and conducting collaborative research. This partnership cannot be just between the government and private sector, it should take into account the sentiments of ground level workers, who are at striving to support themselves, their families, community, governments, the country as a whole and the world at large.

Real happiness would be realised when the results of the research reach an individual to help him or her take an informed decision that makes everyone happy.

To stress on the new goal, being the use of data and information obtained from resources as on date to assist the agrarian community in drawing better yields and higher profits, this can be optimised by digitising the farm and the farmer. Especially right now, with the onset of COVID-19 and the social-distancing protocol affecting labor and agricultural input availability, smart agricultural technologies such as precision agriculture and Unmanned Air Vehicles (UAVs) etc., can be used effectively to manage agricultural fields remotely.[5]

It can be argued that the motive of pushing digital innovation in agriculture alone is not enough to decide results. External factors such as erratic climatic conditions and policy changes, both nationally and across borders, can contribute heavily towards the lack of desired yields. Technological advances, in that case, become a one-stop solution to combat these factors and molding policies or foreign relations in terms of encouraging such advances as well as highlighting innovations amongst all, seems a guaranteed win-win.

This paper aims to touch upon all such salient features of the industry, including regulation, best practices in the industry, etc., from the perspective of an important stakeholder in the framework: the "seed industry", and hopes to serve as a contributor towards achieving a digital agricultural economy.

Regulation of the agriculture sector

i. The Constitution of India

Before we begin to analyse the extent of integration of digital farming, best practices in agritech as on date, the impact of climate change and the technology necessary to halt the effects etc., it becomes relevant to understand from where the relevant policies draw their strength and how the sector is regulated.

The Constitution of India (Constitution), under Article 246, specifies the allocation of powers and functions between the Centre and the States. The Seventh Schedule of the Constitution contains the Union List, State List and Concurrent List. 'Agriculture' is part of Entry 14 of the State List, which means that all the issues related to agriculture are to be addressed by the States.

Agriculture is a peculiar subject that requires proper local knowledge. Every State has different climatic conditions, cropping patterns and different agronomical issues that make it necessary for agriculture to be a subject matter of the State. The legislative intent behind including 'agriculture' in the State List has been to specifically allow the State Governments to draw their own eco-system. The State Governments will, thus, always be in a better position to make laws and reforms for the growth and development of agriculture in India.

That being so, though there is a clear case of division of powers, the Central Government also plays an important role in the implementation of reforms for the sector. Under Article 249 of the Constitution, the Central Government has the power to legislate on any subject, even those in the State List, if the Centre considers this to be necessary in 'national interest'. At times and for various reasons, the State Governments will not be in a position to bring out reforms in the sector. Accordingly, since agriculture is the most important and a sensitive subject, it is highly regulated by different government agencies. The laws, reforms and schemes for supporting the agricultural sector are controlled by both the Centre and the States. Guidelines for agricultural policies are issued by the Central Government's Ministry of Agriculture and Farmers' Welfare. The Central Government directly administers the central schemes and the State Governments regulates the state schemes.

India is also a part of a number of international organisations and conventions such as the World Trade Organisation (WTO), Food and Agriculture Organisation of the United Nations (FAO) of which it is a founding member, International Plant Protection Convention (IPPC), etc. These organisations/conventions and their frameworks serve as the basis for the development of laws in India.

ii. Notable legislations in India in the seed industry

At the core of the sector, the seed is the most important and vital input for agricultural production and productivity. The National Seed Corporation was formed in 1963 under the Ministry of Agriculture and Farmers' Welfare for the implementation of seed legislation in the country.[6] It was in the year 1966 that the Seeds Act was enacted by the Parliament, to designate seed quality parameters, followed by the Seeds Rules in 1968 to comply with the procedural requirements during the implementation of the Seeds Act. Being a legislation brought by the Central Government, it is applicable to the whole of India.

At the core of the sector, the seed is the most important and vital input for agricultural production and productivity.

The authorities set up under the Seeds Act are the Central Seed Committee, the Central

and State Seed Laboratory and the Seed Certification Agency. In addition, there is the Seed (Control) Order, 1983, which mandates obtaining a license to carry on the business of selling, exporting or importing seeds at any place in India.

In addition to the Seeds Act and the rules and orders framed thereunder, the Department of Agriculture and Co-operation under the Ministry of Agriculture, has also implemented a central scheme for the 'Development and Strengthening of Infrastructure Facilities for Production and Distribution of Quality Seeds' (Scheme) for the whole country since 2005-06 and this scheme is currently ongoing,. The objective of the Scheme is to ensure production and multiplication of high yielding certified/quality seeds of all crops in sufficient quantities and to make the seeds available to farmers, including those in remote areas, which are not easily accessible by rail/road on time and at affordable price.[7]

Another notable central legislation is the Protection of Plant Varieties and Farmers' Rights Act, 2001 (PPVFR Act), under which a plant variety can be registered if it complies with the requirements of novelty, distinctiveness, uniformity and stability. Under the PPVFR Act, a separate regulatory authority called the Protection of Plant Varieties and Farmers' Rights Authority has been set up, which is responsible for implementing the PPVFR Act. There are various tests undertaken, as prescribed by the PPVFR Act and the rules made thereunder, including the Distinctiveness, Uniformity and Stability (DUS) test, the DNA test etc., before registering any variety. It goes without saying that the PPVFR Act is a prominent legislation for protecting innovation and intellectual property rights of plant breeders. A more detailed account of the PPVFR Act has been dealt with in the next section.

With specific reference to importing, the Plant Quarantine (Regulation of Import into India) Order, 2003 requires a valid permit for any consignment of plants or plant products to be imported into India. Various screening tests are carried out before issuing such permits.

The Rules for the Manufacture, Use, Import, Export and Storage of Hazardous Micro-Organisms Genetically Engineered Organisms or Cells, 1989 (GM Rules), on the other hand, is the main framework for the import and export of Genetically Modified (GM) materials and designates the competent authorities to regulate GM plants, their composition and internal structure. The GM Rules were introduced through the Environment Protection Act, 1986. The regulatory bodies set up under the GM Rules are the Genetic Engineering Approval Committee (GEAC), Review Committee on Genetic Manipulation, Recombinant DNA Advisory Committee (RDAC), State Biotechnology Co-ordination Committees (SBCC), District Level Committees (DLCs) and Institutional Biosafety Committee (IBSC).

India also became a signatory to the Cartagena Protocol on Biosafety, 2002 (Protocol) on January 23, 2001 and ratified the Protocol on January 17, 2003, which deals with the safe handling, transport and use of living modified organisms (LMOs).

In addition to the above, there are policies, schemes and reforms also specifically aimed at addressing climate change with the intent to promote environmental sustainability. The National Mission on Sustainable Agriculture is one such project that seeks to address

sustainable agriculture in the context of risks associated with climate change, set up under the National Action Plan on Climate Change (NAPCC).[8]

Therefore, by every measure, we can conclude that the Central Government has been highly proactive with its legislations and is constantly upgrading itself with the laws regulating the agriculture sector. Some other specific legislations are also dealt with in this paper in subsequent parts.

It may be noted that crop seed production remains largely unregulated if the seeds are not intended for certification. As mentioned above, if seeds are intended to be certified, their growing and harvesting must comply with the procedure set out by the Seed Certification Agency under the Seeds Act. The object of seed certification is to maintain and make available to the public high-quality propagating material, by ensuring genetic identity and genetic purity. However, such standards do not apply to seeds not covered by the Seeds Act.

By and large, India is still apprehensive of excessive technological changes, in keeping with the rigidity of its colonial rulers pre-independence. That being so, India is also striving to emulate the United States model of less-labour intensive and more capital intensive agriculture

It is also of use to understand the history of liberalisation/ commercialisation of agriculture sector in India. By and large, India is still apprehensive of excessive technological changes, in keeping with the rigidity of its pre-independence colonial rulers. That being said, India is also striving to emulate the United States model of less-labour intensive and more capital intensive agriculture and to shift from a subsistence/ sustenance intent of agriculture to a commercial intent of agriculture. There remain issues in terms of the ownership of the land dedicated to agriculture being largely farmer-owned in India as compared to commercial properties in the United States, the population and demands being greater in the sub-continent as compared to the United States etc. However, the direction in which the sector is developing can be observed effectively, supported by the laws passed by the Government.

iii. Seed unification programmes – International Union for the Protection of New Varieties of Plants[9]

The International Union for the Protection of New Varieties of Plants (UPOV), set up under the International Convention for the Protection of New Varieties of Plants (UPOV Convention) is an international organisation that aims to provide and promote an effective system of protection of plant varieties, thereby encouraging the development of new varieties. The UPOV Convention protects the intellectual property rights of plant breeders, but at the same time permits other breeders to use protected material without authorisation, for their own breeding work, a concession known as the '*breeding exemption*'.[10] UPOV focuses on providing and promoting an effective system of plant variety protection, with the aim of encouraging development of new varieties of plants, for the benefit of society.[11]

In 1994, India signed the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS).[12] In 2002, India also wished to join the UPOV. However, on account of the allegedly restrictive format of the UPOV Convention, i.e., the rights under the convention were severely limiting farmers' rights and were purely intellectual property rights-based and pro-breeders, India was facing immense pressure to not adopt the policies under the UPOV.

It goes without saying that, traditionally, it has been a consistent struggle between farmers' rights and the breeder / innovation rights of private corporations in the agriculture sector.

In 1992, the Convention on Biological Diversity (CBD) provided for "prior informed consent" of farmers before the use of genetic resources and "fair and equitable sharing of benefits" arising out of their use. In 2001, the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) recognised farmers' rights as the rights to save, use, exchange and sell farm-saved seeds. National governments had the responsibility to protect such farmers' rights.

It goes without saying that, traditionally, there has been a consistent struggle between farmers' rights and the breeder/ innovation rights of private corporations in the agriculture sector. However, since India was giving in to farmers' sentiments and not joining UPOV, there was pressure on the Central Government to bring out a parallel legislation to protect plant breeder's rights, by the pharma and biotech entities.

It is in this background that India introduced the PPVFR Act in2002, which aims to maintain the balance between TRIPS and the protection of farmers' rights. Bearing in mind the latest necessity to protect breeder rights and the updated standards in seed quality, it also has become imperative to amend the Seeds Act and bring out a legislation more in keeping with the changing times.

Therefore, the Seeds Bill was introduced in 2004 first and amended in 2010 and 2019.[13]

Section 14 of the Seeds Bill, 2019 mandates compulsory registration of seeds as opposed to the Protection of Plant Varieties and Farmers' Rights (PPVFR) Act. Therefore in a situation where a seed is developed by a breeder (even if it is derived from a traditional variety), they will have exclusive rights to market that particular seed. In addition, the Seeds Bill does not require all the information required by the PPVFR Act. Therefore, private companies are free to claim a derived variety as their own.[14] Indian policy has thus consciously encouraged the development and growth of private seed companies which has led to the takeover of more than 50% of India's seed production by the private sector as of today. It is no surprise that certified seeds have higher and more/ stable yields than farm saved seeds.[15]

It has been argued, on that front, that this freedom under the Seed Bill is to the advantage of the corporates only and since the registration / benefit-sharing with farmers is solely under the PPVFR Act and is voluntary, the farmers may derive no advantage from this arrangement.[16] There are several advantages, in fact, to the private seed entities, including

the bar on re-registration of PVs after a certain period, compensation for failure in performance of products, etc. which is not the case under the current Seeds Act. It remains to be seen what the final legislation shall be.

iv. The Regional Comprehensive Economic Partnership Agreement[17]

With an intention to create a multilateral trading system between the members of the Association of Southeast Asian Nations (ASEAN), the Regional Comprehensive Economic Partnership Agreement (RCEP Agreement) was introduced by the ASEAN Plus One Free Trade Agreements (ASEAN)(India) in 2011. The objective of the RCEP Agreement was to establish a modern, comprehensive, high-quality and mutually beneficial economic partnership that will facilitate the expansion of regional trade and investment and contribute to global economic growth and development.[18]

India already has a number of Free Trade Agreements (FTAs) with multiple RCEP members. However, these agreements have not proven to be economically beneficial to India so far, as exports to partner countries have either decreased or continued at the same level.[19]

In light of the above, it has become necessary to examine the pros and cons of the RCEP Agreement on the agriculture stakeholders in India.

If India signed the RCEP Agreement, the tariff rates will reduce significantly. On the

face of it, this rapid dismantling of tariff barriers could prove costly for a number of Indian enterprises that are not globally competitive.[20] Countries such as China and Vietnam are large markets which have high manufacturing power and capabilities [21] and can easily utilise the reduced trade barriers to break into the Indian markets with their produce. Since India's goal, at the moment, is to make its industry more efficient instead of de-industrialising prematurely,[22] there are chances that the domestic market may be compromised if India signed the RCEP Agreement as Indian manufacturers and farmers especially small, family-owned farms may not be in a position to compete with the international players.[23] It may be noted here that India allows 100% FDI in the seed sector which only means foreign corporations' taking over of the Indian markets is inevitable.[24]

It is also clear that the RCEP Agreement may result in restrictions on seed saving and seed exchange at a time when, under the extreme pressures of climate change, farmers need more diversity in their fields. Furthermore, it could increase their dependence on external inputs and raise their costs of production.[25]

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According to the Asia Pacific Seed Association, farm-saved seeds account for 80-90% of all seeds used in Asia. Farmers select crops based on a number of considerations, including soil type, dietary preferences, livestock needs, weather patterns, water availability and local culture. They have long traditions of saving and freely exchanging seeds amongst themselves, crossing different varieties and storing seeds for the next sowing season. However, these traditions need a fresh look.

It is also important to note that a chapter in the draft RCEP Agreement also states that the signatories shall have to sign and ratify the UPOV. As mentioned above, India has been opposing UPOV and has also introduced the PPVFR Act that provides a viable alternative to UPOV to the Indian plant breeders.

However, this clause in the RCEP Agreement could be to the advantage of the private corporations, considering that the UPOV works in favour of such corporations. The accepted understanding seems to be that, on the pretext of boosting trade among the sixteen nations, the RCEP Agreement will undoubtedly deepen corporate concentration in the food and agriculture sector and offer powerful rights and profitable market to multinational corporations (MNCs).[26]

Not only that, the reduction in trade guards will invariably contribute to the improvement of international trade relations and increase the market size. Member countries of the RCEP Agreement contribute around 30% of total GDP[27] of India and if the RCEP Agreement is implemented in in its letter and spirit, India can also witness an increase in the employment opportunities.[28]

As a natural consequence to the variety of schemes and policies set in place by both the Central and State Governments, as well as the possible effects of the international treaties/ conventions on the Indian agricultural sector, the need for technological inclusion has

been recognised and the concept of 'digital farming' has taken shape. The next section deals with these concepts.

The idea is to give farmers access to timely valuable insights so that they can adopt best practices to manage farms more efficiently, thereby reducing losses and maximising profits.

Introduction to digitalisation of agriculture

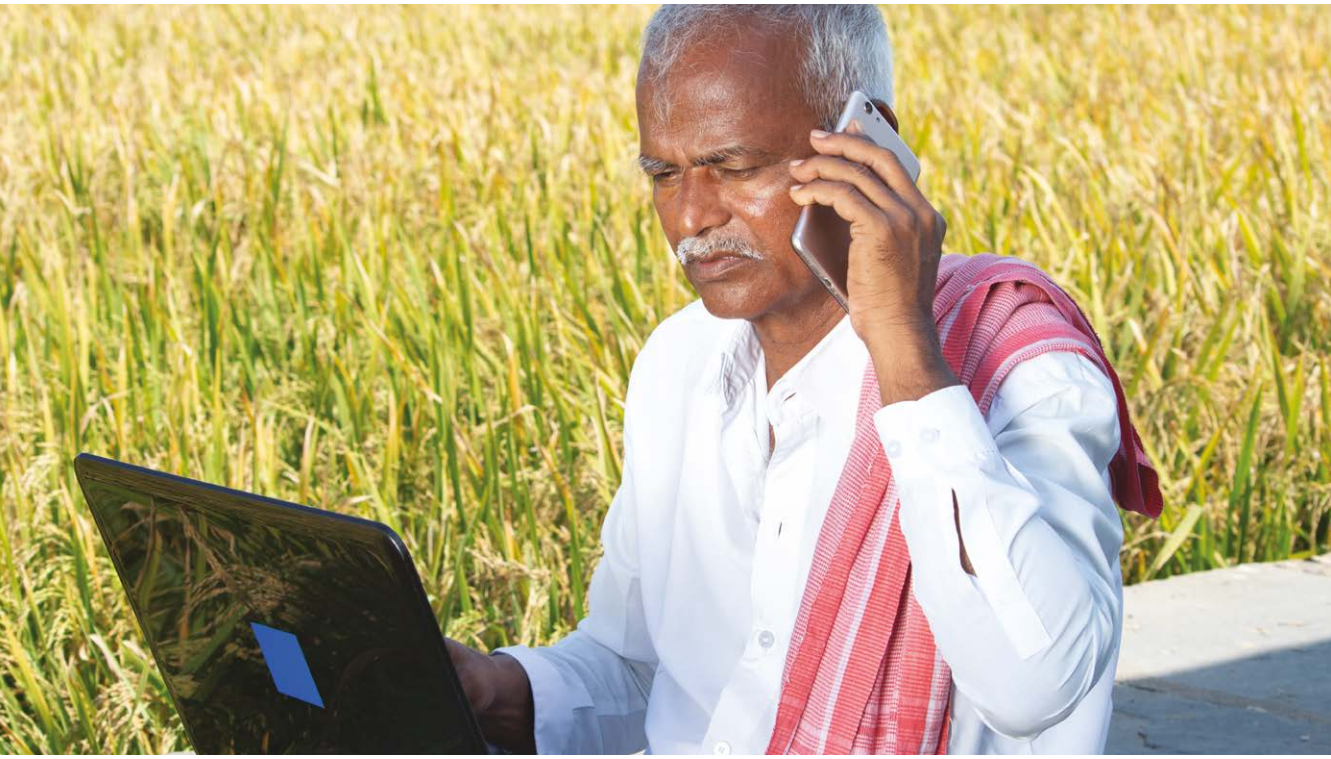
Digital farming can be defined as the use of technology by farmers to integrate financial and field level records for complete farm activity management.[29] The idea is to give farmers access to timely valuable insights so that they can adopt best practices to manage farms more efficiently, thereby reducing losses and maximising profits.

Digital farming is the integration of precision farming and smart farming, achieved through implementation of intelligent software and hardware. Precision farming is also popularly defined as a 'technology-enabled approach to farm management that observes, measures and analyses the needs of individual fields and crops'. As the name suggests, precision farming is the Internet of Things (IoT) in agriculture and relies on the use of sensors, drones, robots and cameras, which are installed on farms to record data. Data of each plot can be analysed to provide information on soil, weather, crop, growth patterns and give actionable geographically relevant and timely insights to optimise productivity of each plot on the farm.[30]

Drones used for spraying and weeding can reduce agrochemical use incredibly. Robotics within agriculture can improve productivity and result in higher and faster yields. The most innovative piece of digital transformation is the ability to use machine learning and advanced analytics to mine data for trends. Machine learning can predict which traits and genes will be best for crop production, giving farmers all over the world the best breed based on their location and climate.[31]

Some advantages of digital farming, on the face of it, are: crop reports and insights: easy reporting on-the-go, a robust and flexible system for farm management, geo tagging for accountability and accurate predictability, standard package of practices, alert log and management (pest infection etc.), satellite and weather input based advisory, readily available and accessible management through smartphones and PCs and near real time monitoring.[32]

While technology is being rapidly infused into the farming sector bearing in mind the necessity of farmers themselves, the corporates in the sector, including the seed



manufacturing and producing companies can also utilise digitalisation on every step, including:

- seed research and development to seed selling, this can be in terms of seeds-based research and development (R&D), which is a venture of field trials and careful observation and selection;
- usage of technology to record data on field, particularly detection of crop growth, stress and health, Management Information Systems (MIS) for better monitoring;
- processing of seeds after harvesting, especially assisting with traceability of the source of seeds using QR codes; and
- managing entire seed distribution and sales through digital farming and use applications such as SmartFarm or SmartRisk to detect weather fluctuations etc.[33]

Government initiatives for the development of digital infrastructure:

To give a soft nudge to technological progress in India, the Central Government has launched and thereafter expanded its *Digital India* program, launching new initiatives and broadening the scope to the agricultural sector. Information and communication technologies (ICTs) are created and infused by the government at mass scale in rural areas, such as mobile phones and SMS messaging, are changing the way farmers track weather

patterns, access market information, interact with traders and government agencies and get paid for their crops.[34] According to a recent World Economic Forum (WEF) article, growth in the agricultural sector can be at least twice as effective in reducing poverty as growth in other sectors and interventions that incorporate new digital technologies have been shown to accelerate agricultural growth.[35]

The Central Government, on its part, has launched the following schemes and policies to assist rapid digitisation:

- Creating a virtual agricultural market, which serves as a common electronic platform allowing farmers to sell their produce to buyers, anywhere in the country. For this an amount of INR 2bn has been set aside for the creation of this National Agriculture Market online trading portal.

- Launching of the *Prime Minister Krishi Sinchai Yojna* (PMKSY),[36] to expand irrigation – A sum of INR 500bn have been allocated for setting up irrigation projects in rural areas, to achieve convergence of investments in irrigation at the field level. One of the objections of PMKSY is to enhance the adoption of precision irrigation and other water saving technologies (more crop per drop), Information Communication Technology (ICT) interventions through the National e-Governance Plan Agriculture to be made use of in the field of water use efficiency, precision irrigation technologies on farm water management, crop alignment etc.

- Developing a digital agri-stack enabling online marketplaces and smart agriculture.[37]

- Setting up of regulatory Institutions, state agricultural universities, Krishi Vigyan Kendras,[38] kisan call centres, regional research institutes, farmer-producers' organisations, rural financial institutions, insurance companies, among others;

- Setting up of the National Agricultural Innovation Project, to promote sustainable rural livelihood for people living in disadvantaged areas through technology-led innovation systems. This project promotes integrated farming system models, the m-Krishi Fisheries Advisory Service, a mobile application tool for enhanced fish catch with reduced time and fuel etc.[39]

Technological progress in the seed industry

i. History of innovation in the seed industry

In the past 30 years, India has seen a tremendous growth and development in the seed industry. As a first step, the National Seed Project was carried out in 3 phases, Phase-I (1977-78), Phase-II (1978-79) and Phase-III (1990-1991), to strengthen seed infrastructure.[40] The New Seed Development Policy (1988-1989) played a significant role in providing the Indian farmers with the best seeds and planting techniques. It also opened the gates for the appreciable investments by private individuals and MNCs in the Indian seed sector.

Over a period of time, it became apparent that the seed industry needs to be ready for a future that has higher adoption of precision agriculture practices – both in seed production and normal cultivation. The way forward was understood to involve a collective movement towards higher technology in the agriculture field by all players concerned.

Over a period of time, it became apparent that the seed industry needs to be ready for a future that has higher adoption of precision agriculture practices – both in seed production and normal cultivation. The way forward was understood to involve a collective movement towards higher technology in the agriculture field by all players concerned.

For instance, seed variability within the farm, using seed metering devices, customising sowing of seeds based on different characteristics of seeds, as per the field conditions, seed treatment customisation based on soil type and the characteristics, etc., could all be potential improvements in the area. [41] Seed companies could also develop technology to delay the application of treatment till the point of sale and customise it as per the requirements of the farmer. Seed companies could also explore the options to design simple sensors for such kind of factors.

Input subsidy / credit availability are thee main factors influencing faster and better adoption of precision agriculture and seed companies have an important role in the education and adoption of these methods by the farmers. Seed and fertiliser companies are now increasingly using digital / social networking platforms such as WhatsApp, Zoom and Microsoft Team to connect with farmers to promote and sell their products, and in a year, agricultural output is set to surge.[42]

ii. Best practices

It is observed that it is crucial for the seed industry to focus and work on the following: [43]

- address the shortage of certified seeds;
- focus on producing improved variety of seeds;
- progress in seed certification and production in target countries;
- combat shortage of early generation seed;
- create farmer awareness for creating demand for seed;
- focus on growing technology for efficient manufacturing of seeds; and
- introduce transgenic crops.

To achieve the above, implementation of new technologies is necessary. It is an urgent need for agricultural-input companies to break away from their traditional ways and

adopt new technologies and methods of production. A greater focus is to be given to digitalisation, openness in internal and external collaboration and innovative culture.[44]

The demand of customers is also changing as they are demanding better, healthier and more transparently produced food. Seed manufacturing companies are now emphasising more on adopting new technologies and innovation. Some of the highly practiced methods for seed development by agricultural-input companies are listed below:

- **Seed testing:** It is crucial to understand the existing quality of seeds in order to analyse and adopt a better and more efficient method for further growth. Seed testing involves overall analysis of seeds and seeds are also tested to determine their genetic and mechanical components. This method helps in providing desired results that are helpful for both the producer and purchaser, in terms of success in yield as well as for capturing the market better.[45]

- **Accreditation:** It is a method through which the technical competence of laboratories is verified. An experienced audit team is appointed for such assessment and the criteria is formulated in the ISTA Accreditation Standard,[46] which is based on the internationally agreed generic accreditation standard for testing and calibration laboratories, known as the ISO/IEC 17025: 1999 Standard.[47]

- **Gene-editing technologies:** This method is also known as Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR)/Cas method.[48] Through this technology, new traits can be created in a variety of crops artificially that can further help in better growth. It also makes the crop disease resistant by making improvements in the DNA of the seeds. [49]

- **RNA interference:** This technology helps in suppressing specific genes in the target organism. Through this method, the genes of plants are blocked by inserting short sequences of ribonucleic acid. This helps to overcome the problems of pest management that includes weed and pest resistance.[50]

- **Seed coating:** This technique acts as a bio stimulant that covers the seeds with external materials and helps to protect the seeds from harmful active ingredients such as, ethylene oxide and propylene oxide block co-polymer surfactants.[51]

- **Pelleting technologies:** It is a technology by which inert materials are added to the seeds in order to increase their weight, size and shape. This method of seed pelleting helps to improve the plantability allowing precise metering, spacing and depth of the seed in the field.[52]

- **Electron treatment:** The electron treatment of seeds is based on the biocidal effect of low-energy electrons. The dose is the electron energy that is absorbed in the seed coat. During the electron treatment of seeds, the lethal dose is crucial to combat the

existing pathogens.[53]

- **Plasma coating:** Fungal infection is the most common problem that affects productivity of crops. It can be well treated with the help of plasma seed coating that helps in the control of fungal infection and results in better production.[54]

iii. Public -private partnership model in agricultural innovation

Not just in terms of innovation in procedures and agriculture equipment, but the Indian government has also come up with enhanced research methodologies for increasing pace of innovation. One such model is public-private collaboration for the exchange of information and conducting collaborative research.

There exist several examples of Public-Private Partnership (PPP) models in India, such as MoA-IBM where the Ministry of Agriculture and Farmer's Welfare partnered with IBM towards a pilot study for farm-level weather forecasts and village-level soil moisture data. The State Governments have also forged several partnerships and are moving ahead in the required direction.[55]

There are also a multitude of public-funded institutions researching on several areas such as seed production, farm implements and machinery, disease diagnostics and vaccines, value-addition and post-harvest processing in cereals, pulses, oilseeds, fruits and vegetables, milk, meat and fish, product testing and evaluation. Such public-funded organisations have shown significant results and the ability to absorb uncertainties of payoffs. The Indian Council of Agricultural Research (ICAR) itself deals with a number of disciplines and commodities in crops, horticulture, animals, fisheries, engineering and resource management.[56] A table containing a list of such institutes assisting in innovation is given below:[57]

S. No.	Institution	Number
1	ICAR Institutes	
	Central Research Institutes	65
	National Bureaux	6
	Project Directorates	13
	National Research Centres	14
2	State Agricultural Universities	63
3	Deemed Universities	4
4	Central Agricultural University	3

Institutional Infrastructure in India

While we have examined the concept of digital farming and its best practices etc., an important aspect related to the sector, especially with regard to the driving force for the innovation is 'climate change'. A look at this important aspect is imperative.

Climate change and its impact on agriculture sector

i. Impact of climate change

Discussions surrounding climate change and its impact on our lives have been the center of attention. On the international front, in 1990, the Intergovernmental Panel on Climate Change (IPCC) first released its report, that summarised the scientific understanding of climate change, impact on agriculture and forestry, natural terrestrial ecosystems, hydrology and water resources, etc. It highlighted important uncertainties regarding timing, magnitude and regional patterns of climate change, but noted that impacts will be felt most severely in regions already under stress, mainly in developing countries.[58]

In 1997, the Kyoto Protocol to the United Nations Framework Convention on Climate Change required parties to promote sustainable forms of agriculture in light of climate change considerations.[59] In 2015, to replace the Kyoto Protocol, the Paris Agreement was signed and India had pledged to better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change, particularly agriculture, water resources, health and disaster management.[60]

According to experts, *"the agriculture industry is a big player in the climate change debate. On the global level, agricultural contributions to greenhouse gas emissions exceed those associated with the transport sector and nearly rival those of the industrial sector as a whole."*[61]

However, many experts are optimistic about the ability of the agricultural sector to affect changes and slow down the rate of climate change. Certain sociologists and political scientists in the United States have noted that, *"In terms of reduction strategies, much of the pollution associated with agriculture happens in the supply chain. Further up the supply chain, there are transportation, manufacturing, and storage issues associated with emissions. Some members of the supply-chain closer to consumers are interested in targeting on-farm emissions as a way to reduce their products' carbon footprints."*[62] Most of the emerging programmes and proposals accordingly also deal with the carbon content in soils.[63]

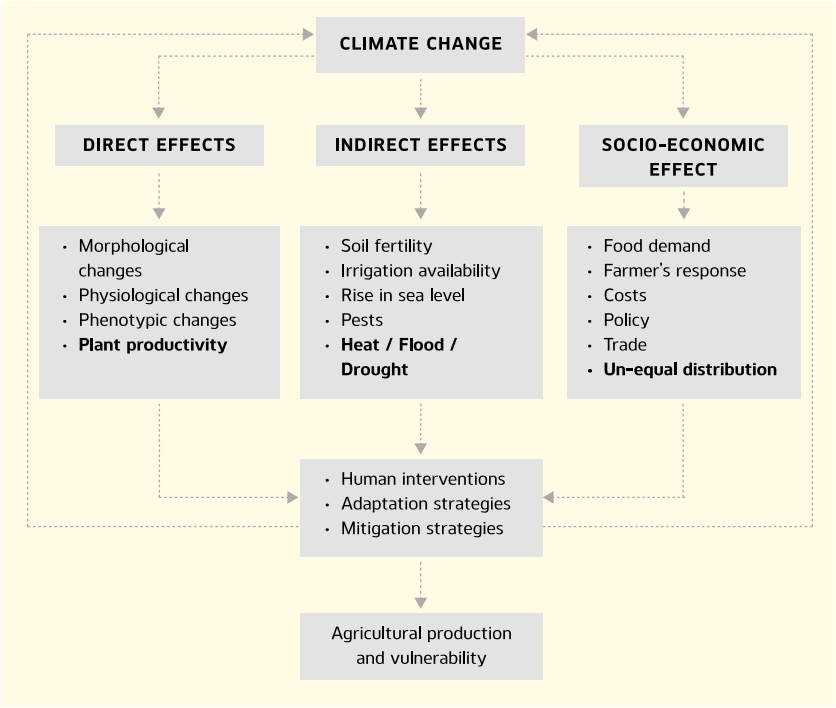
"In terms of reduction strategies, much of the pollution associated with agriculture happens in the supply chain. Further up the supply chain, there are transportation, manufacturing, and storage issues associated with emissions. Some members of the supply-chain closer to consumers are interested in targeting on-farm emissions as a way to reduce their products' carbon footprints."

In the United States, which is the world's largest emitter of carbon and greenhouse gases, agriculture accounted for only 6% of total carbon dioxide equivalent emissions in 2007, corresponding to 413.1 teragrams of CO_2-e. The Indian agriculture sector, on the other hand, contributes roughly 31% of our country's total

emissions, equal to 379,723 gigagrams of CO_2-e[64].

India's agriculture has been predicted to suffer more than any other country's as a result of these climate impacts. Projected surface warming and shifts in rainfall could decrease crop yields by 30% by the mid-21st century. Reductions in arable land with resulting pressures on agricultural output are also forecasted for the Indian terrain.[65]

Climate change affects crop production by means of direct, indirect and socio-economic effects as described in the following table.[66]



Direct, indirect and socio-economic effects of climate change on agricultural production

Rise in temperature is likely to also increase the water requirement of crops due to high rate of evaporation demand and crop duration due to forced maturity. National Centre for Biotechnology Information (NCBI) studied the impact of simulated rise in temperature of one degree by 2020 (over the base year of 1990) in major crops (maize, groundnut, pigeon pea and cotton) grown in Andhra Pradesh and observed that there is a need for excess water requirement than usual. The crop duration has also been observed to decrease by 1-2 weeks. The table containing the results of the study, as conducted across the agro-climatic zones of the State of Andhra Pradesh, is reproduced below:

[67]

Projected changes in crop water requirements and crop duration of major rainfed crops in Andhra Pradesh by 2020

Station	Agro-climatic zone	Crop	Increase in water requirement (mm)	Reduction in crop duration (weeks)
Anakapalli	North Coastal	Maize Groundnut	51.7 61.3	1 1
Anantapur	Scarce Rainfall	Groundnut Red gram	70.1 174.3	1 1
Jagtiyal	North Telangana	Cotton Maize	60.5 49.0	2 1
Rajendra-Nagar	South Telangana	Red Gram Groundnut	114.5 73.0	2 1
Tirupati	Southern	Groundnut	73.0	1

It goes without saying that every concern in the sector is inter-linked and having a domino effect on other concerns. Accordingly, the exports of Indian seeds and the foreign investments flowing into India can also be adversely impacted, in the near future, if the negative climate conditions persist and the breeders / seed manufacturers are unable to reverse the effects on the produce.

ii. Way forward

Decision makers now need research results to make informed choices about new agricultural technologies and to devise and implement policies to enhance food production and sustainability in light of the climatic fluctuations. There is now a greater concern about decline in soil fertility, change in water table, rising salinity, resistance to many pesticides and degradation of irrigation water quality in north-western India.[68]

It is clear that over time more nutrients have been removed than added through the fertilizers and the farmers have to apply more fertilizers to get the same yield they were getting with less fertilizers 20-30 years ago. Changes in temperature and in precipitation patterns and amount are influencing soil water content, run-off and erosion, salinization, biodiversity and organic carbon and nitrogen content. The increase in temperature will also lead to increased evapo-transpiration.[69] There is a need to quantify the specific regional soil-related problems and the effect the global environmental change will have on soil fertility and its functioning for crop growth and production.

Accordingly, plant breeders and research institutions from India, such as International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) have been increasing their efforts to breed crops that are resilient and can survive in extreme weather conditions. Innovation and advancement in the crop breeding of traditional grains remains the key to mitigating the effects of a changing climate on food production, hunger and the livelihoods of farmers in developing parts of the world. There are tools to dissect and quantify the

environmental impacts on the crops and this can help to develop highly targeted products to these particular circumstances.[70]

While it is safely established that innovation in crop breeding is the main solution to battling adverse climate change, it is also imperative to examine the impact of such change on the business of seed manufacturing.

iii. Technology as a solution

As discussed earlier, crop growth, development, water use and yield under normal conditions are largely determined by weather during the growing season. Even with minor deviations from the normal weather, the efficiency of extremely applied inputs and food production is seriously impaired.[71]

An example of variation/ modification in seeds to immunise from climate fluctuations, is the development of FIS (Fertilization Independent Seed) mutants that are capable of producing partial seeds without fertilisation and are also very useful in ensuring food security, considering the emerging climate change challenges and the stress of large and dense populations in countries such as Bangladesh.[72]

Cultivation of indigenous crops also has the potential to make agriculture climate smart, genetically diverse and sustainable. The most important benefits of local landrace crops are their field resistance to different prime pest and diseases and their high adaptability to the climatic conditions of the land. Responsive to organic methods of agriculture, these crops are resilient to disturbed weather events and climate variability.[73]

While combating climate change requires modifying seeds for retaining yields, elevation of CO_2, a phenomenon likely to be caused due to climate change has been observed to result in significantly higher seed yield. Studies on the effects of elevated CO_2 on castor beans, on their growth, flowering and yield, have indicated that, under irrigated conditions where water is not a limitation, it is possible to realize higher yields due to elevation of CO_2.[74] An improvement in effective spike length (12% and 15%), spike weight (46% and 47%), capsule number (65% and 98%), capsule dry weight (46 and 54%) and seed weight (155% and 167%) of primaries were recorded with CO_2 enrichment at 550 and 700 ppm, respectively.

Even while exploring on options to safeguard seeds from the ill effects of weather, seed companies can cash in on the possible advantages of elevated CO_2 levels or such other benefits arising from adverse climate conditions, to their benefit and modify seeds accordingly.

Open top chambers and Free-air CO_2 Enrichment (FACE) technology are currently being used for the study of the response of crop plants to the elevated CO_2. Results from such studies have shown an increase in plant photosynthetic rate and crop yield. Accordingly, not all effects of climate change are a hindrance to the sector of seed manufacture and crop growth. Thus, even while exploring on options to safeguard seeds from the ill effects of weather, seed companies can cash in on the possible advantages of elevated CO_2 levels or

such other benefits arising from adverse climate conditions, to their benefit and modify seeds accordingly.

Having noted the effects of climate change and the options to overcome the difficulties, we may now move on to look at the export potential of seeds in India.

Export potential of seeds in India

India's seed industry is growing at a great pace. The time is not far when India will be able to capture the global market and become the biggest exporter of seeds in the international market.[75] It is relevant to note that the value of the seed industry even today is worth INR 180bn approximately.[76]

It is a matter of pride that majority of the seeds used by the farmers are produced in India. The rate of import of seeds in India is very low as compared to other countries. At present, the annual global seed trade is US$14bn and India's exports are less than INR 10bn per annum. Therefore, India has a lot of potential to dominate the seed industry.[77] The major reasons that make India suitable for becoming the biggest seed exporter are the varied agro-climatic conditions that help in manufacturing different variety of seeds, support of strong legislation and focus of the government on agricultural sector, high value pollinated vegetables, field crops and flower seeds, presence of skilled human resources and involvement of experts in seed testing to ensure quality management and the presence of MNC knowledge post liberalization.[78]

India also has national and international research institutes that give an added benefit to the companies to develop their research capacity.[79]

India is also a member of Organization for Economic Co-operation and Development (OECD) and has been subscribing to its seed schemes since 2008. The main aim of joining such schemes was to promote seed exports with other nations by increasing its overall percentage of exports in the global market.[80] The listing of Indian seeds with the OECD, guarantees the quality of seeds that can be imported by countries participating in the OECD seed schemes. [81] About 57 nations are registered in such seed schemes. India has registered 95 crop varieties mostly hybrids with OECD seed schemes and another 118 are in the pipeline to be registered.[82]

Over time, the Indian seed industry is growing at a good pace. The industry has grown at a pace of 20.59% in between 2010-2015.[83] It is also on account of greater awareness of using quality seeds among farmers that the industry has seen tremendous growth. This has also resulted in an increasing willingness among farmers to pay higher price for quality seeds. Looking at the growth prospects, the focus has also shifted to increase overall export.

As per the available information on the global

...some major policy changes are required to be put in place to enhance exports, such as the need to modify certain laws, particularly export laws, to ensure a smooth policy for the arrival of seeds from other countries and export of produced seeds will help India to increase the rate of exports with other countries.

trade of 2014-2015, India ranked 16th in the export of fruit and vegetable seeds.[84] Also, India's imports of fruits and vegetable seeds have depicted a declining trend in 2016, when compared to 2015. This decline is reflected not only in quantity but also in value terms.[85] Therefore, some major policy changes are required to be put in place to enhance exports, such as the need to modify certain laws, particularly export laws, to ensure a smooth policy for the arrival of seeds from other countries and export of produced seeds will help India to increase the rate of exports with other countries. Other changes include IP protection parent seeds, simpler procedures for granting approval for seed movement from India, establishment of a separate National Seed Export Promotion Council focused on formulating policies that could help in developing seed exports, establishment of an International Seed Testing Association at State level to keep in mind the norms of other countries and reduce time for clearance, establishment of dry ports near all production centres etc. These measures and assurances may help India to attract more foreign countries for seed production.[86] The Agricultural Export Policy, 2018 is one such favourable policy which seeks to boost India's agricultural exports to US$ 60bn by 2022.

India is well known for the production of GM Cotton for the purpose of exports.[87] A study of the procedures adopted for export of GM Cotton could be of assistance to seed companies across the territory of India. Further, with the help of diversification in goods eligible for export, India will also be able to increase its chance of becoming the largest exporter of seeds in the world. India definitely has a potential to capture 10% share in the global exports of seeds by 2028.[88]

In short, while India has a huge potential for becoming an export capital of seeds and agricultural products, in order to cash in on such potential and maximise it, there has to be much policy enablement and the requisite infrastructure to support the rapid and heavy exporting of products, not to mention a give-and-take foreign policy from international markets.

Conclusion

While it is not obvious at first blush, the productivity levels in our seed industry, which are an integral part of the agricultural sector, are abysmally low. According to data from the early years of the 2010s, productivity levels in India are way below the world average in major cereals (wheat and rice), pulses and oilseeds and about 20% of pulses and 50% of edible oil requirement of the country are met through imports.

...certain ground realities such as climate change and erratic climatic conditions and introduction of trade agreements such as the Trans-Pacific Partnership (TPP), RCEP by India also affect the expansion of the agriculture sector ...

While technological advancements are globally prevalent, whether requested by and relied upon by the farmers directly, or pushed forward by the corporates and seed companies, certain ground realities such as climate change and erratic climatic conditions and introduction of trade agreements such as the Trans-Pacific Partnership (TPP), RCEP by India also affect

the expansion of the agriculture sector, in terms of GDP/ GAV, or in terms of reducing individual incomes, production yields etc.

Accordingly, while the green revolution led to an increase in agricultural production, the IT revolution in Indian farming must be the next big step. India has a tremendous opportunity to reap the advantage of being an IT giant and revolutionise the farming sector.

Food security and climate change are going to be the two main challenges facing the seed manufacturing sector in the future.[89] Climate change poses a special problem as most of agriculture in India is monsoon-based and will thus be impacted by changing and unpredictable weather patterns.[90] However, there are many ways of mitigating this damage, by adopting new models of production which can survive the severe fallouts of climate change. We have examined some of these models for the purpose of this paper.

One of the mitigation strategies will be to undertake gene-editing/ genetic modification of seeds, so that they are better able to make use of the increased carbon dioxide levels in the atmosphere. Alternatively, there are also subtle changes in microclimate conditions which can be undertaken, such as seed coating with thermostable polymers, amending soil with superabsorbent hydrogels. Along with this, evaluation, screening, conservation and seed multiplication of local landraces will also be effective.[91]

The second will be to shift crop-growing areas towards suitable growing locations and similarly, we may also shift seed-production areas. It is noted that there remains an obstacle to the crop-shifting, in terms of government interference and red tape. There is also a way to increase production by changing the sowing time. These proposals have been made after observing productivity levels in the States of Haryana, Rajasthan and Kerala, in the fields of main cereals such as wheat and rice.

Nonetheless, the ability of seed growers to make these changes is directly linked to the seed system.

In the formal seed system, which operates in developed countries, implementation will be fairly easy and straight forward. On the other hand, under the informal system, which operates in developing countries, current seed production challenges including supply failing to meet demand and poor seed quality will increase with changing climates.[92] In most developing countries, where there are a few commercial seed companies, legislation and supporting activities are not developed and annual seed replacement is very low, informal sources still provide a large proportion of seeds to be sown, either saved from a farmer's own harvest or purchased from a local market.[93] This is true for India also.

Hence, India has deployed a participatory approach, by undertaking the following:

- establishment of seed villages, which involves clubbing a group of farmers into a Self Help Group (SHG) focused on the production of a specific type of seed of their choice, and promotion of community seed banks at village level, which are the integral components of the Food and Agriculture Organization (FAO) administered multilateral International Treaty on Plant Genetic Resources for Food and Agriculture (TPGRFA) agreement. The TPGRFA aims to ensure food security and farmers right.

- to combat deceleration in productivity growth, putting in place policies like the National Food Security Mission (NFSM) and Rashtriya Krishi Vikas Yojna (RKVY), and
- to support seed production by induction of new varieties into seed chain.

Along with these numerous public sector initiatives, the private sector has also contributed by increasing export of crops, technology and agricultural inputs, such as agrochemicals and machinery in addition to seeds and this has trickled down even to the poorer farmers. The National Seeds Corporation has also been undertaking mechanisation of the storage, grading and packaging processes, with fine results.[94]

Despite the above initiatives, it is relevant to note that, on the side of manufacturing, mechanisation still faces numerous hurdles. Yield is a function of varied inputs such as seed quality, fertiliser usage, irrigation facilities and mechanisation. The productivity yields in India suffer on account of fragmented landholdings which impact the level of mechanisation, lack of all-weather irrigation facilities, depleting soil quality due to aggressive use of fertilisers and usage of poor quality seeds as reflected in low seed-replacement ratio.

The inevitable conclusion is that the ability of the global seed industry to provide the necessary quantities of quality seed for agricultural production will be diminished due to climate change unless the seed industry undergoes transformation. Thus, while the existing models are full of promise, there is a lot which remains to be done and the widespread mechanisation of the seed manufacturing processes must be undertaken as soon as possible to combat the ill effects of climate change.

India has, over recent years, also developed a tremendous start-up ecosystem, with favourable policies and schemes. Start-ups such as Ecozen Solutions, which has launched Ecofrost, a portable cold room that maintains low temperature, and FIB-SOL Life Technologies, which has developed low-cost bio-fertilisers that help farmers to improve crop yield and soil quality, are thriving in the Indian economy.[95] The Central Government has recently also initiated the 'Agricultural Grand Challenge', with a specific intent to boost agritech start-ups, to solve problems faced by the agricultural sector in India.[96]

Unlike many other countries, India is blessed with fifteen agro-climatic zones which can be exploited for developing diverse plant and seed varieties. It is needless to state that India certainly has all the tools to perfect and protect its agricultural sector, at the same time to boost business to profit both corporations and farmers. There need only be an increase in policy enablement in order to adopt and reap the benefits of the technological advancements in the sector, not to mention to increase exports and reduce dependence on imports. |

The author would like to extend his gratitude to **Venkatram Vasantavada** *(Managing Director & CEO, SeedWorks International Private Limited)* for his valuable inputs.

The author would also like to thank **Manasa Tantravahi**, *Associate* at the firm for her assistance.

Noorul Hassan is a Joint Partner at the firm.

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