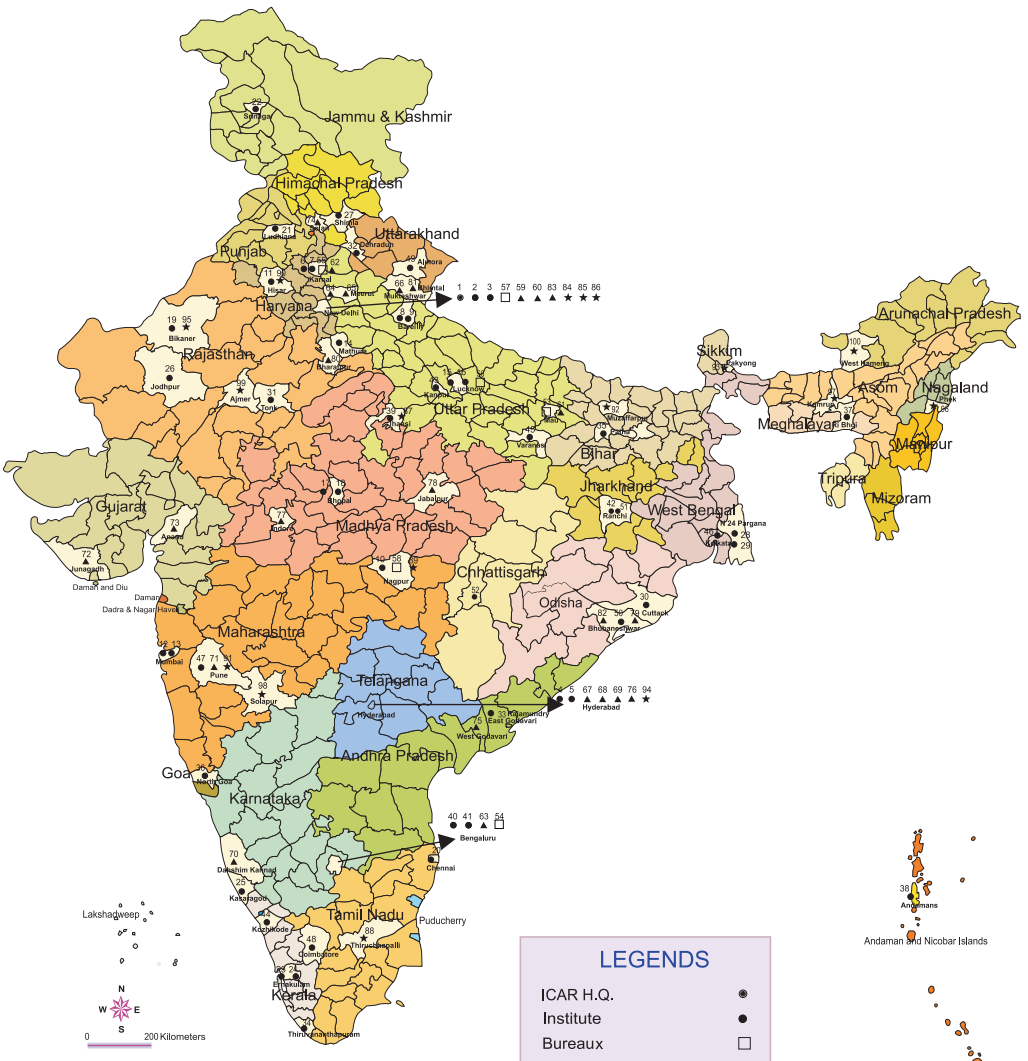
# Vision 2050

Directorate of Seed Research

Indian Council of Agricultural Research

# INDIAN COUNCIL OF AGRICULTURAL RESEARCH

## Institutes, Bureaux, Directorates and National Research Centres

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# Vision 2050

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# संदेश

भारतीय सभ्यता कृषि विकास की एक आधार रही है और आज भी हमारे देश में एक सुदृढ़ कृषि व्यवस्था मौजूद है जिसका राष्ट्रीय सकल घरेलू उत्पाद और रोजगार में प्रमुख योगदान है। ग्रामीण युवाओं का बड़े पैमाने पर, विशेष रूप से शहरी क्षेत्रों में प्रवास होने के बावजूद, देश की लगभग दो-तिहाई आबादी के लिए आजीविका के साधन के रूप में, प्रत्यक्ष या अप्रत्यक्ष, कृषि की भूमिका में कोई बदलाव होने की उम्मीद नहीं की जाती है। अतः खाद्य, पोषण, पर्यावरण, आजीविका सुरक्षा के लिए तथा समावेशी विकास हासिल करने के लिए कृषि क्षेत्र में स्थायी विकास बहुत जरूरी है।

पिछले 50 वर्षों के दौरान हमारे कृषि अनुसंधान द्वारा सृजित की गई प्रौद्योगिकियों से भारतीय कृषि में बदलाव आया है। तथापि, भौतिक रूप से (मृदा, जल, जलवायु), बायोलोजिकल रूप से (जैव विविधता, हॉस्ट-परजीवी संबंध), अनुसंधान एवं शिक्षा में बदलाव के चलते तथा सूचना, ज्ञान और नीति एवं निवेश (जो कृषि उत्पादन को प्रभावित करने वाले कारक हैं) आज भी एक चुनौती बने हुए हैं। उत्पादन के परिवेश में बदलाव हमेशा ही होते आए हैं, परन्तु जिस गति से यह हो रहे हैं, वह एक चिंता का विषय है जो उपयुक्त प्रौद्योगिकी विकल्पों के आधार पर कृषि प्रणाली को और अधिक मजबूत करने की मांग करते हैं।

पिछली प्रवृत्तियों से सबक लेते हुए हम निश्चित रूप से भावी बेहतर कृषि परिदृश्य की कल्पना कर सकते हैं, जिसके लिए हमें विभिन्न तकनीकों और आकलनों के मॉडलों का उपयोग करना होगा तथा भविष्य के लिए एक ब्लूप्रिंट तैयार करना होगा। इसमें कोई संदेह नहीं है कि विज्ञान, प्रौद्योगिकी, सूचना, ज्ञान-जानकारी, सक्षम मानव संसाधन और निवेशों का बढ़ता प्रयोग भावी वृद्धि और विकास के प्रमुख निर्धारक होंगे।

इस संदर्भ में, भारतीय कृषि अनुसंधान परिषद के संस्थानों के लिए विजन-2050 की रूपरेखा तैयार की गई है। यह आशा की जाती है कि वर्तमान और उभरते परिदृश्य का बेहतर रूप से किया गया मूल्यांकन, मौजूदा नए अवसर और कृषि क्षेत्र की स्थायी वृद्धि और विकास के लिए आगामी दशकों हेतु प्रासंगिक अनुसंधान संबंधी मुद्दे तथा कार्यनीतिक फ्रेमवर्क काफी उपयोगी साबित होंगे।

**(राधा मोहन सिंह)**

केन्द्रीय कृषि मंत्री, भारत सरकार

# Foreword

Indian Council of Agricultural Research, since inception in the year 1929, is spearheading national programmes on agricultural research, higher education and frontline extension through a network of Research Institutes, Agricultural Universities, All India Coordinated Research Projects and Krishi Vigyan Kendras to develop and demonstrate new technologies, as also to develop competent human resource for strengthening agriculture in all its dimensions, in the country. The science and technology-led development in agriculture has resulted in manifold enhancement in productivity and production of different crops and commodities to match the pace of growth in food demand.

Agricultural production environment, being a dynamic entity, has kept evolving continuously. The present phase of changes being encountered by the agricultural sector, such as reducing availability of quality water, nutrient deficiency in soils, climate change, farm energy availability, loss of biodiversity, emergence of new pest and diseases, fragmentation of farms, rural-urban migration, coupled with new IPRs and trade regulations, are some of the new challenges.

These changes impacting agriculture call for a paradigm shift in our research approach. We have to harness the potential of modern science, encourage innovations in technology generation, and provide for an enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy, and technology dissemination need to be given priority. Multi-disciplinary and multi-institutional research will be of paramount importance, given the fact that technology generation is increasingly getting knowledge and capital intensive. Our institutions of agricultural research and education must attain highest levels of excellence in development of technologies and competent human resource to effectively deal with the changing scenario.

Vision-2050 document of ICAR-Directorate of Seed Research (DSR), Mau, Uttar Pradesh has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario 35 years hence, towards science-led sustainable development of agriculture.

We are hopeful that in the years ahead, Vision-2050 would prove to be valuable in guiding our efforts in agricultural R&D and also for the young scientists who would shoulder the responsibility to generate farm technologies in future for food, nutrition, livelihood and environmental security of the billion plus population of the country, for all times to come.

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# Preface

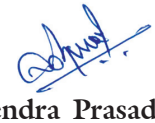
Seed is an essential input for crop production. Farmers' access to quality seed of superior varieties is key in increasing agricultural productivity and production. For any successful quality seed programme, it is mandatory to produce sufficient quantity of seed with appropriate research backup on various aspects of seed technology viz., production research, maintenance, quality assurance, processing, storage, quality enhancement etc. In a bid to shoulder the responsibility, ICAR established Directorate of Seed Research during December 2004 by upgrading AICRP-NSP (Crops) which was launched during 1979-80. Directorate of Seed Research, through its flagship projects viz., AICRP – NSP (Crops) and ICAR Seed Project under the aegis of Indian Council of Agricultural Research has made significant achievements by developing appropriate technologies relevant to seed through basic, applied, strategic and anticipatory research leading to seed security which is a prerequisite for assuring food security. Apart from technology development; capacity building with focus on skill intensification, technology dissemination, model deployment (farmers participatory approach and seed village programme), employment generation, commercial orientation addressing gender outlook i.e. women entrepreneurship, expansion of seed activity in untapped areas are significant contributions of DSR.

Indian domestic seed market accounts for 2 billion USD out of 45 billion USD international seed market i.e. approximately 4.45 % of world's total market share. Whereas seed exports from India are to the tune of abysmal 0.6 %, which needs to be amended through appropriate policy support and well defined strategies viz., compliance to appropriate & internationally acceptable quality assurance standards. Thorough pondering is needed on aspects such as development of climate ready seed production technologies, identification of alternative provenances to tackle climate change, standardization of seed testing and quality assurance protocols amid GM crops, research on flowering synchronization and seed maturation (especially in hybrid rice and single cross maize hybrids as they are future game changers), more sophistication in seed processing (thermo seed treatment technology), quality enhancement (second and third generation enhancement strategies), packing and handling, appropriate back up of legislations

(pro-farmer, pro-export orientation), streamlining seed testing and certification modus operandi on par with global conventions (ISTA, OECD etc.), due importance to informal seed system (upgrading quality of farm saved seed), technology dissemination, capacity building and model deployment for carving special niche for Indian seed in international domain. Public Private Partnership (PPP) approach can be sought after for correcting imperfections in seed marketing. Globally sustainable food security is possible when resources in both public and private sectors are pooled and synergised. There is enough space for both public and private seed industries, joint planning and execution of activities can be done for delivery of effective end product to farmer. Directorate has taken the initiative to address challenges that Indian Seed sector is facing today and in near future. VISION 2050 document has been prepared to provide a road-map for the course of research amid major challenges like shrinking natural resources, deleterious effects of climate change etc., which are expected to affect the seed security. This document provides priorities, adaptation of participatory models and partnership norms with different stakeholders in seed domain at national and international level to address the challenges of enhancing Seed Replacement Rate and Varietal Replacement Rate, which are essential for food security through seed security.

I express my sincere gratitude to Dr. S. Ayyappan Secretary, Department of Agricultural Research and Education and Director General, Indian Council of Agricultural Research for his invaluable guidance in preparing DSR VISION 2050. I am thankful to Dr. J. S. Sandhu, Deputy Director General (Crop Science) and Dr. J. S. Chauhan, Assistant Director General (Seed) who had taken keen interest and provided valuable inputs in formulation of this document. I also appreciate the efforts made by my colleagues, Dr. Udaya bhaskar K., Mr. Umesh R. Kamble, Dr. S. Natarajan, Dr. Dinesh K. Agarwal and other ICAR - DSR staff in bringing out this document. I am sure that VISION 2050 would provide a direction to leverage the power of science for achieving high quality research in seed science and technology and quality seed production in the country.

*"Quality seed releases pressure on agriculture, seed is the basis for much of the food we consume; let us give rightful importance which it deserves"*



**(S. Rajendra Prasad)**

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# Acronyms

| | |
|---|---|
| CNTs | Carbon Nano Tubes |
| GIS | Geographic Information System |
| GM | Genetically Modified |
| GPS | Global Positioning System |
| GURT | Genetic Use Restriction Technology |
| ICT | Information & Communications Technology |
| IPR | Intellectual Property Rights |
| ISF | International Seed Federation |
| ISTA | International Seed Testing Association |
| MAS | Marker Assisted Selection |
| MIR | Molecular Impulse Resonance |
| NSAI | National Seed Association of India |
| OECD | Organization for Economic Co-operation and Development |
| PGPR | Plant Growth Promoting Rhizobacteria |
| PPP | Public Private Partnership |
| SPT | Seed Production Technology |
| SRR | Seed Replacement Rate |
| TOT | Transfer of Technology |
| UPOV | International Union for the Protection of New Varieties of Plants |
| USD | United States currency in Dollar |
| VRR | Varietal Replacement Rate |

# Context

*"Seed is a bridge of hope between present and future and is inevitable for life's continuity"……*

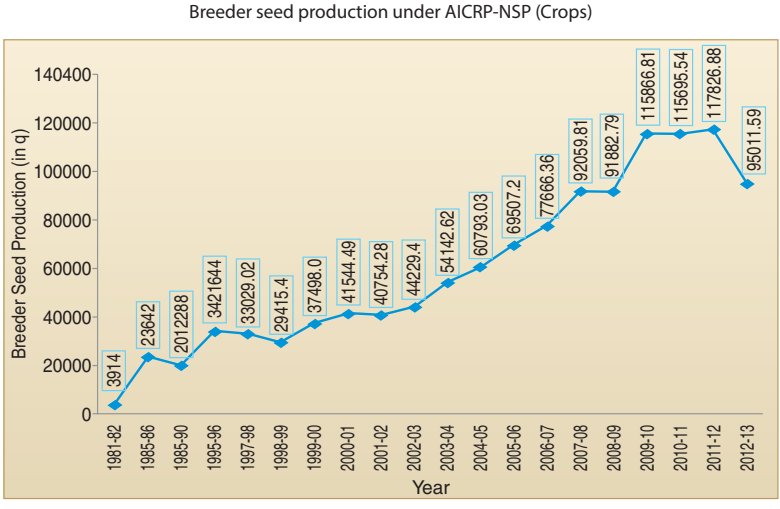
Seed is the decisive input for sustained agriculture production and is paramount for realizing the potential of all other inputs without which the investment on inputs such as fertilizer, water, and pesticides will not pay desired dividends to the farmers. Use of quality seeds alone could increase productivity by 15-20% indicate the critical role of seed in agriculture. As Indian economy is basically agrarian due to sheer number of people directly or indirectly dependent on agriculture, the role of seed in India's context is far greater significant. Food security is fundamental for sustaining progress of India with a billion plus population. India has witnessed a momentous food grain production of 265.0 million tonnes during 2013-14 from meager 50.5 million tonnes during 1950-51, which is largely credited to the use of quality seed of improved varieties/ hybrids, improved farming practices along with ingenuity and industry of Indian farmers. Quality seed production and making available at right time i.e. seed security is having a positive correlation to food security needs of the country.

Realizing the importance of seed, Indian Council of Agricultural Research (ICAR), an apex organization for conducting, coordinating and monitoring agricultural research and education in India, mounted serious efforts to streamline country's seed programme by launching AICRP-NSP (Crops) in 1979-80 aimed at production of basic seed with a separate project coordinating unit dedicated exclusively for nucleus and breeder seed production and to carry out seed technological research. This was elevated to Directorate paving the way for establishment of Directorate of Seed Research (DSR) in 2004 envisioning the referred mandate. Another milestone project in quality seed production was 'ICAR Seed Project – Seed Production in Agricultural Crops and Fisheries' launched in 2005 aiming at provision of infrastructural facilities in seed domain under National Agricultural Research System (NARS) throughout the country.

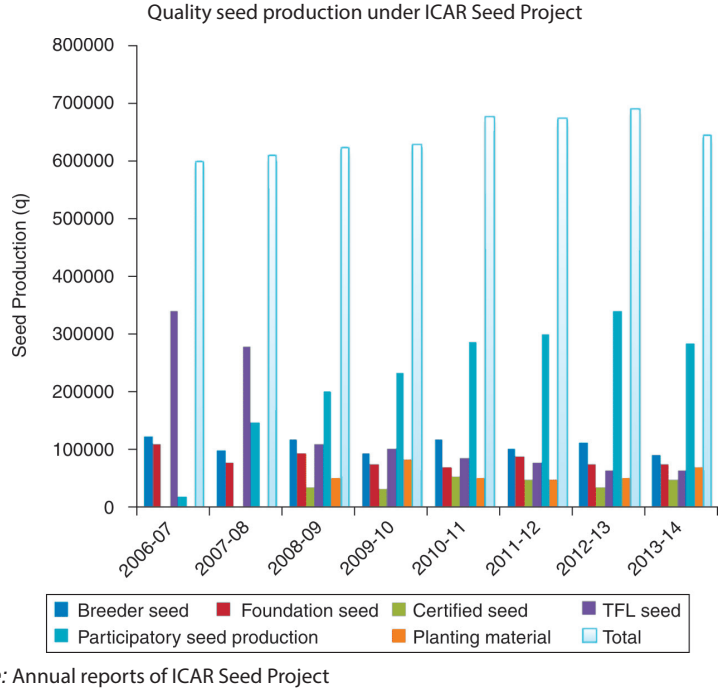
Since inception, DSR strived towards achieving excellence, which is clearly manifested in the form of surge in quality seed production and enhancement in the horizons of seed technological research. ICAR seed Project, lead to infrastructure establishment in seed domain

under NARS. DSR generated valuable information and contributed significantly to seed technological research.

## Significant achievements in quality seed production under AICRP – NSP (Crops) and ICAR seed project "Seed Production in Agricultural Crops"




*Source:* Annual reports of AICRP – NSP (Crops)




*Source:* Annual reports of ICAR Seed Project

# Challenges

On global front, population will breach 9 billion mark by 2050 with India leading the march, i.e. each farmer must feed more people with declining land and water resources. On the verge of climate change, seed research is the key to unlock the potential of technologies. In Indian context, from a long period of time, seed requirement of farmers is mainly met by farm saved seed, i.e. still 65 % of the farmers are using their own saved seed or seed distributed among them. Making the quality seed available at right time is greater challenge rather than production per se. Seed, being the principal input in determining productivity, seed replacement should be given utmost priority. Amelioration of skewed SRR, i.e. the percentage of area sown out of total cropped area by using certified/quality seeds other than farm saved seed is the major challenge. Even though there is slight improvement recently, still a long way ahead in making the quality seed available at farmers' doorsteps and for achieving 100% SRR, which will herald the era of quality seed driven growth in agriculture sector.

**Seed Replacement Rate in different crops and its variation across states**

| Crop | National Average SRR (%) | Highest SRR (%) | | Lowest SRR (%) | |
|---|---|---|---|---|---|
| Paddy | 37.5 | 82.0 | Andhra Pradesh | 9.0 | Uttarakhand |
| Wheat | 32.6 | 42.0 | Maharashtra | 11.0 | Jammu & Kashmir |
| Maize | 54.1 | 100.0 | Karnataka | 5.0 | Odisha |
| Jowar | 25.9 | 65.0 | Andhra Pradesh | 11.0 | Tamil Nadu |
| Bajra | 61.4 | 100.0 | Gujarat | 29.0 | Karnataka |
| Bengalgram | 18.4 | 78.0 | Andhra Pradesh | 4.0 | Rajasthan |
| Blackgram | 29.2 | 77.0 | Haryana | 3.0 | Chattisgarh |
| Greengram | 26.7 | 94.0 | Uttar Pradesh | 1.0 | Odisha |
| Redgram | 17.5 | 55.0 | Andhra Pradesh | 2.0 | Odisha |
| Groundnut | 24.5 | 50.0 | Andhra Pradesh | 0.5 | Madhya Pradesh |
| Mustard | 63.6 | 78.0 | Rajasthan | 13.0 | Odisha |
| Soybean | 35.9 | 100.0 | Andhra Pradesh | 11.0 | Rajasthan |
| Sunflower | 61.2 | 100.0 | Andhra Pradesh | 8.0 | Madhya Pradesh |
| Cotton | 10.4 | 100.0 | Andhra Pradesh | 2.0 | Odisha |

*Source:* Directorate of Economics & Statistics, Ministry of Agriculture, GOI {2012} (http://dacnet.nic.in/eands)

**Quality seed requirement of major crops in the country (Assuming 100% SRR)**

| Crops | Gross cultivated area (million ha) | Seed Rate (kg/ha) | Certified seed requirement (000 tonnes) | SMR | Foundation seed requirement (000 tonnes) | Breeder seed requirement (tonnes) |
|---|---|---|---|---|---|---|
| Rice | 45.6 | 50 | 2280.0 | 100 | 22.8 | 228.0 |
| Wheat | 27.2 | 125 | 3400.0 | 20 | 170.0 | 8500.0 |
| Sorghum | 7.7 | 15 | 115.5 | 160 | 0.7 | 4.5 |
| Pearl millet | 8.7 | 5 | 43.5 | 200 | 0.2 | 1.1 |
| Maize | 8.0 | 20 | 160.0 | 80 | 2.0 | 25.0 |
| Pigeon pea | 3.4 | 15 | 51.0 | 100 | 0.5 | 5.1 |
| Chickpea | 8.2 | 80 | 656.0 | 10 | 65.6 | 6560.0 |
| Groundnut* | 6.2 | 100 | 620.0 | 8 | 9.7 | 1210.9 |
| R&M | 6.3 | 5 | 31.5 | 200 | 0.2 | 0.8 |
| Soybean | 8.9 | 75 | 667.5 | 16 | 41.7 | 2607.4 |
| Sunflower | 1.9 | 10 | 19.0 | 50 | 0.4 | 7.6 |
| Cotton | 9.5 | 12 | 114.0 | 50 | 2.3 | 45.6 |
| Jute | 0.8 | 5 | 4.0 | 100 | 0.04 | 0.4 |
| Total | 142.4 | | 8162.0 | | 316.1 | 19196.4 |

* Groundnut foundation seed requirement is calculated on basis of two stage c/s production

Another major problem of seed chain is Varietal Replacement Rate (VRR). Even though with more than 4500 varieties, notified and available, indents for basic seed and its further multiplication is restricted to few varieties. Many improved varieties, which are location specific, resistant to biotic and abiotic stresses never saw the light of the day, may be due to below par extension activities. Hence special focus will be given on improvement of VRR, which certainly paves the way for improved productivity levels manifest in the form of increased production.

Regarding seed technological research, focus will be given on basic research relevant to floral biology, pollination, seed development and maturation studies in a bid to attain better seed recovery. Refinement of seed production technology in varied crops will be given highest priority, thereby enhancing profitability of seed production. Globally, the contemplated research work relevant to fields of seed testing, quality assurance and seed quality enhancement is at par excellence. In order to match global requirement and to strengthen India's position in international market, there is need for cutting edge infrastructure

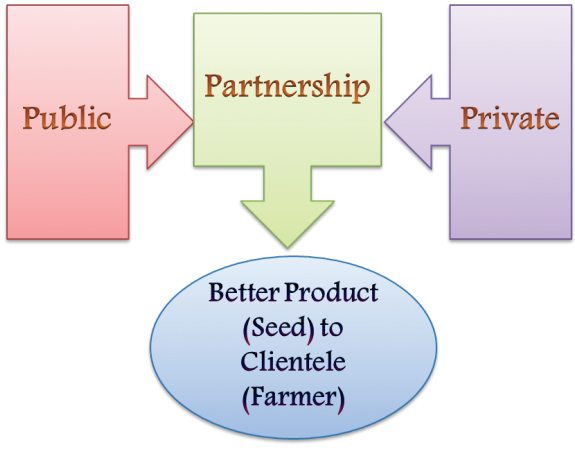
and world class laboratories accredited to international seed agencies/ institutes. Collaborative research projects in partnership with private seed sector to deliver desired outputs that benefit farming community of the country should be formulated.

# Operating Environment

DSR established in the year 2004, in Mau district of Uttar Pradesh, has responsibility of conducting and coordinating of Seed Technological Research and quality seed production under NARS.

Right from farmers' choice to a particular variety, source of seed, production technology, protection, processing, storage and marketing, at every juncture seed is playing the role of either influencing or being influenced indicates its pivotal role. Contribution made by private sector in quality seed production especially of high value and low volume crops and in seed research with respect to quality assurance and quality enhancement are worth of appreciation. Private sector is playing its part in generating healthy competition, which will ultimately benefit the farmer. Consortia approach shall be pondered upon thoroughly, so that public and private sectors can complement rather than compete each other for synergistic output to enhance the visibility of Indian seed in international market.

There would probably be a sea change in operating environment by 2050 pertinent to status of domestic seed market share, seed exports and research requirements based on enhanced demand for steeper production and productivity, climate change etc. and in terms of available research tools such as genomics, phenomics, transcriptomics, nanotechnology and Information and Communications Technology (ICT).



# New Opportunities

Indian seed industry is poised to grow @ 15% and expected to touch USD 3.2 billion by 2016 (Anonymous, NSAI 2012 report), and if the same trend continues, shall place Indian seed market in top three positions in international seed domain. We must be proactive to explore export potential and create enabling environment. This can be achieved through a well planned strategy and targeted implementation plan. The nature gifted biodiversity and the diversity in agro-climatic conditions offer exciting opportunities for India to be globally competitive in producing and promoting a number of seed crops for export.

Future growth drivers of seed industry could be hybrids in crops viz. paddy, maize, mustard, pigeonpea followed by vegetables and flowers. India is a major player in the global paddy market with about 43.0 million ha cropped area. Although having largest acreage under paddy cultivation, productivity is stagnant at about 3.5 t/ha. Hybrid rice could be a game changer for India, as only 4.1 % of area is under hybrid rice. Total paddy seed turnover is Rs. 21.8 billion in 2011. It could be increased to Rs. 42 billion over the next four years, if 50 % of the cultivated area is covered by improved varieties and 10 % by hybrids (ISTA News, 2012). Over the past few years, world demand for maize is increasing due to its alternative usages like biodiesel production. Globally, India ranks 4$^{th}$ in production as well as acreage with average productivity of 2.5 t/ha. In future, global warming is likely to have detrimental effect on wheat and rice cultivation, under such situation, maize, a C4 Plant may play decisive role in mitigating harmful impact of climate change. Therefore, focus on quality seeds of hybrid maize will largely contribute to growth of Indian seed market in near future.

Technological breakthroughs in relevant fields of seed science and technology are quite commendable both at national as well as international domain. Even though there is some catching up is needed to gear to the needs of global market. Seed testing and quality assurance is one area where lots of policy, infrastructure and human resource support is needed. Establishing world class facilities for seed testing, certification and to match requisites of international conventions *viz.,* UPOV, ISTA etc., so that seed from India can carve its niche in international trade. Estimated commercial world seed market is 45 billion USD out of which India's share is 2 billion USD (ISF, 2013). Even

though, India is sixth in position in terms of value share, there is ample scope to amend the figure mentioned and for excelling in international seed trade. India with diverse agro-climatic zones, unlimited options for crops and probably with largest research man power has an enormous opportunity to stamp authority on world seed front.

Expanding the know-how of conventional seed science and technology *viz.,* floral biology, pollination, seed development, maturation and seed production technology *per se* can create formidable opportunities in maximizing the productivity levels thereby food and socio-economic security in the country. Regarding seed quality enhancement, whole spectrums of opportunities are awaiting. Second and third generation seed quality enhancement strategies will play a vital role in giving an altogether new dimension to seed. Seed designing will emerge as a futuristic technology, where seeds are fabricated with all necessary additives that give adequate planting value across diverse agro-climatic zones by insulating them against biotic and abiotic stresses. A new era of seed designing is going to be unraveled in near future, where seeds are bought or sold on number basis making it as the most precious input of cropping system.

**Opportunities under Seed Quality Augmentation**

- Deployment of intelimer additives for coating/pelleting of seed
- Utilization of advanced polymer systems (thermo/hydro) for seed designing
- Smart delivery systems (nanotechnology) for controlled release of analytes
- State of art disinfection techniques (thermo/plasma treatments) for seed protection
- Deployment of OMICS technologies in seed quality improvement
- Development of Image Analysis Systems for seed & seedlings quality assurance

**Prospects of seed export**

India's share in global seed exports is about 0.6 % (ISF, 2012). To give a boost to seed export, India decided to participate in OECD Seed Schemes in five categories viz., Grasses and legumes; Crucifers and other oil or fibre species; Cereals; Maize and sorghum and Vegetables.

OECD Seed Schemes is one of the international frameworks available for certification of agricultural seeds moving in international trade. Its objective is to encourage use of seeds of consistently high quality in participating countries. Complying to internationally acceptable procedures of seed quality assurance shall certainly boost our seed exports and enable India a force to reckon with in global seed realm.

### Perspectives

Regarding seed technology research, both public and private sectors made significant achievements. Public sector contributed immensely to the standard seed production enhancement technologies whereas private seed sector is slightly ahead with ultramodern seed processing, storage and quality enhancement technologies. In high value and low volume crops, utmost priority is for seed quality enhancement (seed designing). Private sector contributed significantly for external (seed coating, pelleting and seed applied additives) and as well as internal designing (seed priming and seed upgradation). Second generation [intellicoat, MIR (Molecular Impulse Resonance), electron treatment and magnetic treatment] and third generation (nanotechnology) technologies offer ample scope for collaboration among both the sectors, so that quality seed production demands of the country can be met. Public sector may adopt flexibility in institutional setup, business outlook for which proactive policies are needed. Under changing legal and regulatory regimes, private seed sector needs support of public Sector regarding sharing of breeding material, consultancy services and participation in Transfer of Technology (TOT) trainings on seed production and related technologies. Advantages of synergy between public and private sectors under Intellectual Property Rights (IPR) regime is desirable for better product development and management of fiscal resources.

### Farmers' perception

There is surreal change in farmers' perception and majority is viewing seed as an assurance for bumper yield rather than input cost. Bt cotton, vegetables, hybrid rice and single cross maize hybrids are glaring examples of farmers' investment in improved quality seed. Though there is need to create same sort of brand identity with reference to high volume and low value crops through innovative strategies. As unorganized sector accounts for major share as 65 % of farmers still use farm saved seeds, technological intervention for quality upgradation of farm saved seed is need of the hour. Availability of quality seed of improved varieties/ hybrids at appropriate time and affordable price is essential to address seed security. Apart from mere production; capacity building with focus on skill intensification, technology dissemination, model deployment like farmers' participatory approach and seed village programme needs to be further strengthened.

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# Goals and Targets

Under the adept support and guidance of ICAR, DSR flourished in achieving new heights in seed technological research and quality seed production. Being the focal point of quality seed production coordination and seed technological research, DSR envisions working on futuristic technologies, which in turn lead to seed security and food security.

### Seed Production Research

Future of agricultural production will largely depend upon development of improved varieties/ hybrids in various crops, supported by efficient, cost effective seed production technologies. Diversification of areas for seed production and development of appropriate seed production technology needs to be focused for expansion of seed production system in the country. Identification of alternative/specific areas for quality seed production and mapping of disease free seed production zones may go a long way in popularizing seed production technologies in non-traditional areas.

#### *Climate Resilient Seed Production*

The reproduction success in plants is determined largely by the environmental conditions prevailing during the growing season. Among the various environmental factors, moisture and temperature have direct influence on reproduction. Early reproductive processes like pollen viability, stigma receptivity, anthesis, pollination, fertilization, and early embryo development are all highly prone to moisture and/ or temperature stresses. Failure of any of these processes increases early embryo abortion, leading to poor seed set, thus limiting the seed yield. The physiological mechanisms of reproductive failure under stress are not well understood. Hence, considerable efforts should be made to study the effect of climate change on seed production of various crops to develop suitable crop management technologies and mitigate the adverse effects on the reproductive phase.

#### *Development of crop and location specific organic seed production technologies and harmonization of organic seed standards*

Organic agriculture for sure shall carve its justified niche in future, hence gearing up to the needs of development of crop and location

specific organic seed production technologies deserve high priority. Since seed is starting point of production systems, organic seed (production technology, field and seed standards) is inevitable for location –specific, producer community based organic agriculture.

- Development of seed production technologies in major crop species to improve seed yield and quality together with conservation of natural resource base
- Identification of alternative/ specific areas for quality seed production and mapping of disease free seed production zones
- Development of different models of participatory seed production and establishment of village seed banks
- Developing alternative methods like self incompatibility & apomixis systems for hybrid seed production
- Standardization of organic seed production techniques and seed standards
- Harmonization of regulatory standards in tune to the needs of international seed domain
- Formulation of certification protocols and seed standards in potential untapped crops like medicinal and aromatic plants.

*Application of GIS/GPS/ Remote Sensing for higher seed productivity*

GPS/GIS applications includes guidance of equipment viz., micro irrigation facilities, fertilizer/pesticides applicators and tillage implements; mapping of pests and diseases to reduce excess overlaps and skips and enable towards precision in seed production.

Quality seed production basically is the enterprise to make available the seeds of highest genetic purity and also possess quality attributes such as high germinability, vigour and freedom from insect pests and diseases. There are different strategies well in place to ensure the highest genetic integrity.

**Proprietary Seed Production technology (SPT):** Technology involves using a genetically modified (GM) line to propagate a male-sterile line which is then used as one of the parents to produce hybrid seed. The genetic modification is not inherited by the hybrid. The principle of SPT could be applied to other crops, particularly cereals (wheat and rice), some of the pulses and oilseeds where there is a need for better hybrid systems and where alternative male sterility systems are yet to be developed.

**Setting up of effective standard operating framework to tackle novel technologies viz., Genetic use restriction technology (GURT):** GURT is the name given to proposed methods for restricting the use of genetically modified plants by causing second generation seeds to be sterile. There are conceptually two types of GURT:

- Variety-level Genetic Use Restriction Technologies (V-GURTs): This type of GURT produces sterile seeds, so the seed from this crop

could not be used for further propagation, but only for sale as food or fodder. If technology ever gets approval this would have an immediate impact on the large number of indigenous farmers who use their farm saved seeds, and instead they would be forced to buy seeds from seed production companies. Consequentially, resistance to the introduction of GURT technology into developing countries is strong.

- T-GURT: A second type of GURT modifies a crop in such a way that the genetic enhancement engineered into the crop does not function until the crop plant is treated with a chemical that is sold by the developer. Farmers can save seeds for use each year. However, they do not get to use the enhanced trait in the crop unless they purchase the activator compound. The technology is restricted at the trait level, hence the term T-GURT.

### Seed Quality Assurance/Varietal Maintenance and Testing

Innovation has different meaning to scientific community, industry and farmers. As far as the farmer is concerned, all the scientific innovations would have to be of little value unless he gets refined end product (seed), which is genetically pure (true to type) and posses other desired qualities namely, high germination and vigour, sound health etc. Different seed testing protocols currently used in India need to be upgraded on the lines of international standards of seed testing such as ISTA, AOSA and OECD for better seed quality assurance and easy access to international seed trade. Use of biochemical and molecular markers including electrophoresis of proteins, isoenzymes and DNA fingerprinting involving first and second generation markers for establishing the distinctiveness of varieties may supplement Grow Out Test in genetic purity testing. Particular attention needs to be paid on distinguishing closely related and essentially derived varieties (EDVs). Further, focus should be on development of user friendly molecular detection kits for fast and accurate identification of varieties, hybrids, pathogens and GMOs. With increasing biotechnological intervention in different crops and development of GM crops, research on certification standards, isolation distance from non GM crops and cost effective kits for detection of transgenes by using micro array chips and proteomic approaches needs to be carried out.

### Seed Biotechnology

Genomics should be undertaken to discover gene/s governing dormancy, germination and longevity and stress tolerant genes to

- Development of national data base for DNA profiles of crop varieties
- Development of DNA bar coding system for tracking the breeder seed production and supply system.
- Validation/up-gradation of field and seed standards/protocols: isolation distance, sample size, physical purity and ODV
- Standardization of minimum weed seed standards and development of interactive software for weed seed identification
- Developing mechanisms for uniformity in seed testing and reporting, & facilitation in establishment of ISTA accredited laboratories
- High performance phenotyping and second generation imaging technologies

produce superior quality seeds. Transcriptomics of seed development to unzip molecular regulation of improved seed characters is an area, where immense potential lies for quality improvement.

### Seed Quality Enhancement

Plethora of avenues where seed enhancement can be effectively tapped

### Second Generation Seed Applied Additives

Transient expression is modus operandi of this technology. Expression occurs in plant but not carried forwarded to progeny

### Intellicoat Technology

Polymer-based technology used for controlling the time of seed germination through seed coating. It is based on the Intelimer polymers, which differ from other polymers in that they can be customized to abruptly change their physical characteristics when heated or cooled through a pre-set temperature switch. By coating the seeds with Intelimer polymers that have required pre-set temperature switch mechanism, the time of germination of the coated seeds can be adjusted and the synchronization problem of parental lines in hybrid seed production could be prevailed over. Besides, this technology also helps in relay cropping system.

### Cold Plasma Coating

Seeds could be coated with different (hydrophobic/hydrophilic) gaseous polymers under high energy and low temperature. Under such conditions the gases attain the plasma state and get coated on the seed surface. Application of this technology has been shown to control the speed of germination.

### Molecular Impulse Response (MIR)

It is a non-chemical, energy-based enhancement, which is supposed to provide improved tolerance to different types of abiotic stress effects, often increasing germination, accelerating maturity, and raising yields. MIR uses an extremely low energy electron shower to create a short-term rise in free radical levels inside the cells of seed. This causes the cells natural defense to produce more anti-oxidants, which disable the free radicals and leave the cell with less free radicles and more anti-oxidants than before the process began.

### Bioprospecting

Application of biological agents to crop seeds have focused on rootcolonizing bacteria, termed rhizobacteria. PGPR (Plant Growth Promoting Rhizobacteria) comprise those rhizobacteria that include beneficial effects on plants during colonization. Benefits of PGPR include promotion of plant growth and biological control of plant diseases. In addition to causing yield increase, often induce early season gowth promotion that can be manifested in various forms, including enhanced seedling emergence, increased biomass of roots and/or foliage, and earlier flowering.

### Nanotechnology for Seed Quality Enhancement

Seed treatment with carbon nano tubes (CNTs), array of nano particles (gold/silver/borates) is a whole new field, yet to be fully unraveled. Application of Nanotechnology in seed science research is still at nascent stage, and its full potential is yet to be tapped. Right from designing smart delivery systems (CNTs, nanofibres) loaded with nutrients/PGRs/pesticides for sustained release, dormancy breakdown, longevity enhancement, vigour augmentation, physiological process regulation and molecular modification, that means it is a research realm with infinite boundaries and shall reorient the entire concept of seed enhancement.

### *Advances in seed quality (vigour) assessment*

#### *CF-analyzer*

Vigour (apart from germination, desiccation tolerance and longevity) is developed during the maturation or ripening stage, chlorophyll presence on seed has a direct link to maturity and can be fast but precisely measured through its fluorescence.

### Single Seed Oxygen Consumption System Technology

Oxygen consumption is directly related to energy production, so this technology gives us a perfect view on the different quality aspects of seeds such as; imbibition time, speed of germination, homogeneity and energy availability during the germination. This system is thus revolutionary in seed testing for basic research and commercial operations alike. It provides fast and accurate measurements of the different germination aspects of a seed lot. In addition, data is more robust and defining than traditional germination tests.

### Second Generation Imaging Technologies

3D imaging of seedlings with an array of cameras from different angles, point cloud model is used to create a virtual plant model. Based on model, software classifies seedling into different classes (e.g. normal/ abnormal).

### Infrared Thermography

Infrared Thermography can be used to predict whether a quiescent seed will germinate or die upon water uptake. When a dry seed takes up water, the sugar within the seed dissolves, and this process cools the seed down. For example the temperature of a single pea seed falls rapidly by 2 to 3°C. Viable seeds maintain cool temperatures because they break down storage reserves into sugar. Aged seeds also fail to break down their reserves, or can only break them down after a phase of repair, delaying the thermal profile. Such thermal profiles of a seeds can be recorded and analyzed to construct a library of "thermal fingerprints" that allows distinguish between viable and dead seeds.

### Seed Health

Seed sector has a twofold responsibility in the area of seed health: to deliver sufficiently healthy seed to farmers and seed producers, and to respect international phytosanitary regulations.

- Revisiting of field and seed standards for seed-borne diseases
- Bio-management (seed priming) of seed borne diseases and standardizing novel modus operandi (new molecules, MAS etc.) for seed insect pests management
- Application of novel molecular tools (DNA chips) to identify seed-borne pathogens
- Harmonisation of national regulations on phytosanitary issues

### Seed Processing and Storage

- Development of ultramodern seed processing and storage technologies like thermal seed processing facilities (high precision seed protection, high throughput process) at various cooperating centres under the ambit of DSR network projects.

### Seed Economics

*Seed Demand Assessment/Forecasting*

One of the key elements of a seed system is how actual demand is assessed considering factors like weather, market, farmers' skill. The current demand assessment procedure does not consider the possibility of shift in demand due to weather and market conditions creating considerable mismatch between demand and supply. There is a need to develop seed demand forecasting technique that considers factors such as seed prices, availability and prices of other inputs, cash constraints, weather forecast, and cycle of seed replacement period.

And also there is a need for analysis of investment in R&D with respect to seed technology research vis-à-vis public and private sectors, impacts due to investment activities on Indian seed market size, improved productivity, farmer welfare gains and intellectual property development need to be considered. An analysis of shift in the private and public R&D expenditure with respect to seed research over years and factors responsible for the change has to be studied. This study will help to explore current research opportunities in seed sector. Economic and mathematical modeling tools can be applied to understand the shift in investment structure.

### Human Resource Development

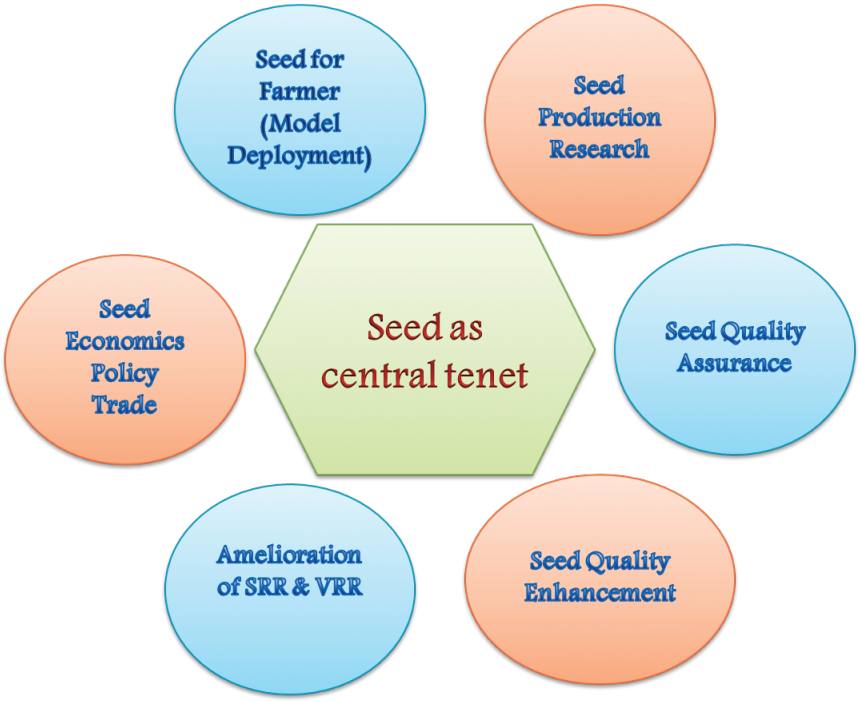
Capacity building with focus on skill intensification, technology dissemination, and entrepreneurship development among women and unemployed rural youth in seed domain shall be the priority.

### Linkages

Linkages of DSR with firms of national and international

- Development of various marketing models aimed at quality seed reach to remote localities
- Establishing e-seed knowledge centres and e-seed modules for augmenting Seed Replacement Rate
- Policy research in quality seed sector with fine tuning of cost calculations for quality seed production
- Ex ante and ex post impact assessment of technological interventions in seed research
- Quantitative assessment of trade impacts due to seed policy reforms and price policy research in quality seed sector

reputation in seed research production, supply, marketing and exports both in public and private sectors address the quality seed production, availability and research issues at local, regional, zonal, national and international level, which in turn facilitate strong and meaningful basic, applied and anticipatory research to support the national strategic seed research plans.



# Way Forward

**Treading to Seed Security.....**

Directorate of Seed Research (DSR) is going to put its best foot forward in a bid to reach the specified goals set, which are decisive in attaining desired productivity, thereby ensuring food and nutritional security to teaming millions of population of India. DSR is envisioning itself as a vital cog in the broader system, striving towards achieving desired levels of quality seed production and making available at farmers' door steps. DSR as a premier institute, dedicated for the cause of playing a leadership role in conducting and coordinating of seed technological research under NARS is endeavoring to excel in global seed realm.

Because of the sheer paramountcy of 'seed' in the sphere of farming systems, DSR is envisaging itself as a national institute with a renewed outlook by expansion of its domain with creation of regional centres thereby enabling the system for developing partnerships and linkages with diverse seed stakeholders in national and international arena.

ICAR-DSR, with 'seed' as a carrier of innumerable technologies will tackle issues such as safe food and food quality through formulation of standards (field and seed) for GM crops and organic seed production, shall address food security by means of seed security and contributes its part in unraveling the much awaited farmer centric ever green revolution meant for assurance of food security & growth, which is central philosophy/success scale for any science.

*Seed reduces the footprint of Agriculture (ISF).*

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## NOTES

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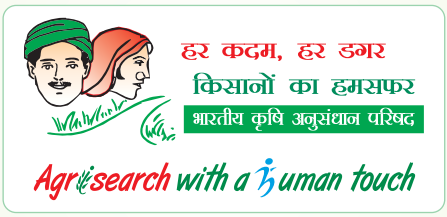
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