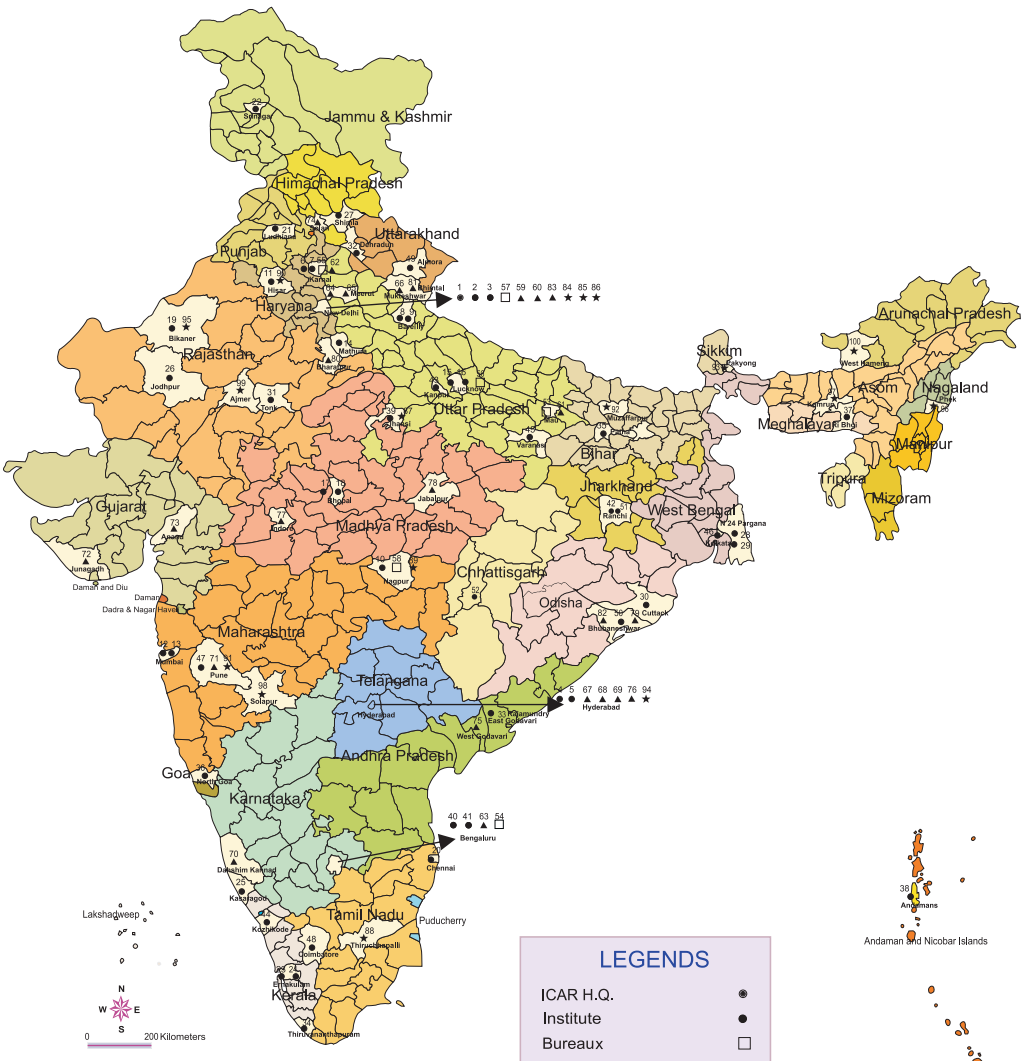
Vision 2050

Central Potato Research Institute
Indian Council of Agricultural Research

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Institutes, Bureaux, Directorates and National Research Centres



● 64 Research Institutes ● 6 Bureaux ● 15 National Research Centres ● 15 Project Directorates

Vision 2050

Central Potato Research Institute
(Indian Council of Agricultural Research)
Shimla

www.cpri.ernet.in

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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-Central Potato Research Institute (CPRI), Shimla 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.

(S. AYYAPPAN)
Secretary, Department of Agricultural Research & Education (DARE)
and Director-General, Indian Council of Agricultural Research (ICAR)
Krishi Bhavan, Dr Rajendra Prasad Road,
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Preface

At the time of inception of CPRI, in the year 1949, India used to produce 1.54 million t potatoes from 0.234 million ha area at an average productivity level of 6.58 t/ha. As per FAOSTAT, the potato production in India during 2013 was 45.34 million t from 1.99 million ha area with a productivity of 22.76 t/ha. It is the hard work of potato farmers, scientists and policy makers that potato area, production and productivity increased over 6 decades by 8.5,29.4 and 3.5 times, respectively. Contribution of CPRI has been adequately recognised by the nation on several occasions, however, potato in India has still to transform from simply a vegetable supplement to serious food security option. Ability of potato to produce highest nutrition and dry matter on per unit area and time basis, among major food crops, made FAO to declare it the crop to address future global food security and poverty alleviation during 2008. Rising number of working couples, rapid rate of urbanization, enhanced tendency of eating out of home, higher disposable income levels of people and important place of potato in fast food items, create an ideal situation for enormous expansion of potato consumption in the near and distant future.

Estimated domestic demand of potatoes in India is 122 million t during 2050. Demand for processing quality potatoes will increase from current level of 2.8 million t to 25 million t in the year 2050. It implies that the demand is expected to increase by 6% ACGR up to 2050, where frozen potato products will have the highest ACGR (11.6%) followed by potato flakes/powder (7.6%) and potato chips (4.5%). On similar lines, the food demand for fresh potatoes will increase from the current 30 million t to 78 million t during 2050 at an ACGR of 2.34%.The demand for seed potato will grow nearly 2.1 time by the year 2050, therefore, highly concerted efforts needs to be directed towards providing desirable quality seed potatoes to all farmers at remunerative prices.

'CPRI Vision 2050' document presents comprehensive analysis of constraints and challenges in the path of meeting our future goals. The document contains elaborated strategy to overcome these challenges and mitigate the constraints. Analysis of strengths, preparedness and work culture of the institute makes me fully confident that the institute will meet not only these expectations but set new global standards.

We are grateful to Dr. S. Ayyappan, Director General ICAR and Secretary, DARE, and Dr. N. K. Krishna Kumar, Deputy Director General (Horticulture Science) for envisaging the significance of long term research agenda and motivating us to bring out the 'CPRI Vision 2050'. I sincerely thank Dr.T. Janaki Ram, Assistant Director General (Horticulture Science), for his constant involvement in the improvement process of this Vision document. Invaluable comments and suggestions of CPRI's RAC chairman Dr. G. L. Kaul helped us improve Vision-2050 considerably. Further, I would like to put on record the sincere efforts of Dr. Rajesh K Rana, Principal Scientist, Division of Social Sciences, Dr. PM Govindakrishnan, Project Coordinator, AICRP (potato) and Dr. VK Dua for providing scientific inputs to give this document its present shape. Role of in-charge PME cell, Dr. Brajesh Singh in providing contents of this document to all stakeholders is duly acknowledged. I am confident that this document will act as a lighthouse for providing clear-cut course of action in order to pursue future potato research and development activities in India.

(B.P. Singh)
Director, CPRI

Contents

Context

A perusal of various R&D efforts and outcomes in the field of agriculture in general and, more specifically the potato, reveals that "Business as Usual" scenario would not hold much longer. We have to anticipate and get ready to tackle much more complex and diverse future challenges in our respective fields. As the time lag between research and development efforts and the final application/adoption of the output may stretch over decades, a long term vision and blueprint of action plan is highly important for any organisation/institute. CPRI Vision 2050 is an effort to envisage long term state of affairs of potato industry in India and formulate a strategy to fulfil national needs through a well-documented plan to tackle anticipated challenges.

Why Vision 2050?

An ideal research agenda should include short, medium and long term concerns of the country with respect to the mandate of an organisation. Research output in the form of technologies comes after considerable time lag while desirable adoption of such technologies takes much longer time.

Future challenges in potato R&D being much more complex and difficult to be addressed, our preparedness has to be much more rigorous, precise and should extend over longer period of time. With every new addition to our knowledge on impending issues like climate change and their implications on potato industry we need to envisage more robust and superior strategies to deal with them. Development of every new vision document of CPRI provides an opportunity to assess the relevance of strategies designed and put forth in the light of unanticipated recent developments having bearing on the future of Indian agriculture as well as potato industry. Based on past experience we can visualise that several of the developments were not possible to be envisioned. Therefore development of a new vision document provides us an opportunity to make midterm course corrections and embark on a better strategy with higher probability of success in the future. CPRI Vision 2050 will serve as a light house for future potato R&D voyage.

Potato in Indian Agricultural Economy

Agriculture, including allied activities, contributed 13.9% of the

GDP at constant prices (2004-05) in 2013-14 (Anonymous, 2014) while this sector still accounts for 54.6% of total employment in the country (Anonymous, 2011). Current share of potato to agricultural GDP is 2.86% out of 1.32% cultivable area. On the contrary, the two principal food crops, rice and wheat, contribute 18.25% and 8.22% of agricultural GDP, respectively from 31.19 and 20.56% cultivable area, respectively (FAOSTAT). It indicates that contribution of potato in agricultural GDP from unit area of cultivable land is about 3.7 times higher than rice and 5.4 times higher than wheat.

Potato being a labour-intensive crop requires about 145 man days for cultivation of one ha of land. Thus nearly 289 million man-days of employment have been generated only for potato cultivation during 2013. Besides, large number of semi-skilled labour is required for carrying out post-harvest operations like transportation, storage, processing, marketing etc. Moreover, about 75% of the total labour force employed in potato cultivation is constituted by the women. Therefore, potato encourages gender equality in agricultural labour market. Input-intensive nature of potato crop helps in overall economic development of the country by supporting other sectors of the economy like industry, finance and services. For example, relatively higher demand of fertilizer, pesticide, farm machineries, cold storage equipment and structures, packaging materials, etc. for potato cultivation enables healthy industrial growth. Similarly, the crop supports services sectors through agricultural loans, insurance, marketing and technical consultancy etc.

Global and Indian Scenario

Potato is the third most important food crop in the world after rice and wheat. Global annual potato production during the triennium ending (TE) 2013 was 370 million t resulting in per capita availability of over 50 kg. As per FAOSTAT, India is the second largest annual producer of potato after China, leaving the Russian Federation far behind (43.1, 88.2 and 30.8 million t, respectively, during TE 2013). Developed countries were the major potato producers as well as consumers till the last millennium. A comparison of potato production growth during TE 2003 and TE 2013 showed that Africa (97%) experienced the highest proportionate growth followed by Asia (Fig. 1). India and China were not only the major contributors to the Asian growth of potato production but being producer of one third global potato, contributed significantly to world potato production. Potato consumption in India and China is accelerating due to increasing industrialization and participation of women in the job market that created demand for

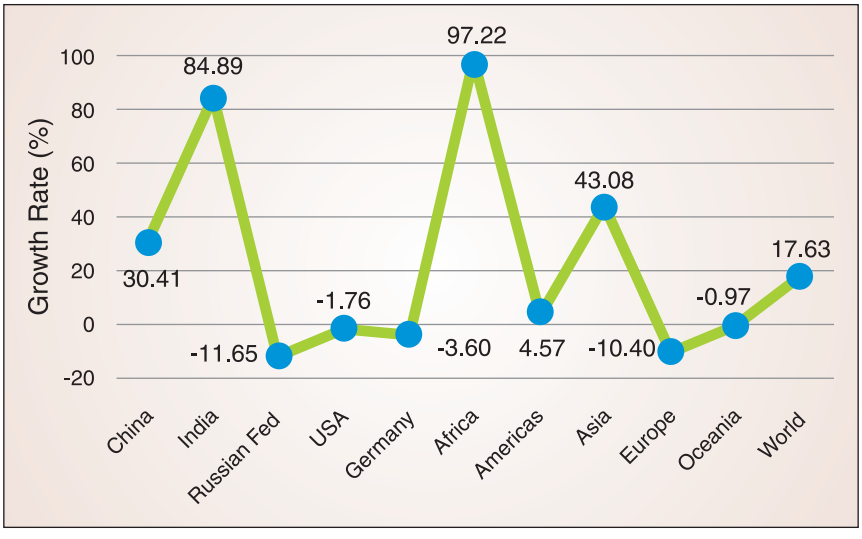

Fig. 1 Potato production growth (%) over major potato producing nations and continents during TE 2003 and TE 2013 (Data source: FAOSTAT).

processed, ready-to-eat convenience food, particularly in urban areas.

During the last decade developed world has experienced fall in per capita potato consumption (Americas, Europe, Oceania, Russian Federation having -8.8, -9.4, -8.3 and -2.4% growth in per capita potato consumption, respectively), while at the same time per capita potato consumption in the developing world showed increasing trend [Africa, Asia, India (in addition to the potato consumption increase due to rapid population growth), China showed 40.6, 25.6, 37.1 and 28.8% growth in per capita potato demand, respectively] during the TE 2001 and 2011 (FAOSTAT). In absolute terms Asia is the biggest gainer in per capita as well as total potato consumption over this period. However, the productivity in most of the developing countries continues to be very low.

Production target

At present in India, about 68% of potato production is consumed as fresh while the rest is utilized as seed (8.5%) and processing purposes (7.5%)or the remaining goes as waste (16%) due to various reasons that includes rottage and wastage during the entire potato supply chain. After accounting for rapid growth of potato processing due to fast economic development of the country (Rana, 2011; Singh and Rana, 2012), lower proportionate growth rate of seed demand (due to higher

Potato Crop

productivity), rise in per capita consumption of fresh potato [rapid urbanisation, future role of potato in food security (Thiele et al., 2010; Singh and Rana, 2013) and fast economic development] and as a result of ongoing efforts to lower post-harvest losses, the estimated demand of potatoes in 2050 is about 122 million t.

In addition to the estimated demand it is likely that potato tubers will be used as animal feed and for other industrial uses such as potato starch manufacturing in the future. The net export of potato tubers from India is also likely to increase in the form of seed potato and processed potato products, from the current average of a meagre 0.1 million t per year. However, due to non existing potato starch industry, absence of trends for using potato as animal feed, and numerous international variables as determinants of Indian export of seed potato and processed potato products, it is difficult to estimate future targets for the said uses of potatoes. However, using professional judgment a target of 3 million t during 2050 is assigned to all these three uses collectively. Hence, we would require potato production of about 125 million t in 2050 (Table 5)at an ACGRs of 3.2%.

Productivity Goal

Productivity and profitability of potato will determine future growth of this crop in India. Considering more or less stagnant cultivable land and impending food insecurity threat in the country we will have to strive very hard in the direction of increasing productivity of the crop. The WOFOST model estimates indicate that at present level of

Potato Tuber

technological intervention the achievable yield of potato in India would be 35.95 t/ha during the year 2050. However, due to the technological advancement at NARS level the achievable yield during 2050 would be 43.14 t/ha.

At present level of farm management practices we are actually able to harvest only 42-45% of the achievable yield. However, an enhanced emphasis on efficient dissemination of farm technologies and consequent improvement in farm management practices in the country, it is estimated that we would be able to harvest 80% of achievable yield in 2050 which would result in estimated yield of 34.51 t/ha. Potato productivity in India is required to rise at an ACGR of 1.46% up to the year 2050 in order to meet this yield target.

Area Requirement

The projected potato area based on the ACGRs of last 40 years is not possible to achieve as country has already about 46% (141.4 million ha) of the total geographical part as net sown area. Further increase in cultivable area in the country is likely to cause huge environmental damage. Fast increment in land used for non agricultural purposes makes this expansion still more difficult. NCAP has forecasted net sown area in the country during 2050 at 142.6 million ha which is more or less same as during 2010. Therefore, primary goal of future potato R&D in India in general, and at CPRI in particular, would be increasing average potato productivity in the country to 34.51 t/ha during the year 2050. The potato production targets as dictated by the corresponding demand

of potatoes for various uses would be met with the adjustment in the area. Higher or lower demand will be reflected in prices which will consequently affect farmers' profitability and ultimately the area under potatoes will automatically be adjusted.

At estimated production and yield targets, we would require 3.62 million ha of area under potato. However, availability of this enhanced area under potato cultivation in future needs to be critically analysed. Higher per unit (area and time) production potential of potato crop compared to other food crops will help getting higher allocation of area under this crop in the future. Rice and wheat have 41.85 and 27.75 million ha area under cultivation in India and potato is generally taken as a sequence crop with both these crops. With the ongoing efforts of developing short duration potato varieties and tropicalization of the crop, faster mobility of perishable crops on account of upcoming dedicated freight corridors of Indian Railways, potato emerging as an important food security option in India, and elevated demand will bring needed area under potato through relative improvement in crop profitability. ❑

CPRI

History

Central Potato Research Institute (CPRI) was established in 1949 at Patna on the recommendation of a working group headed by Sir Herbert Steward, the then Agricultural Advisor to the Government of India. Earlier potato R&D agenda in India was just confined to the seed potato multiplication programme. Later the institute was shifted to Shimla in 1956 and was later handed over to ICAR in April 1966 and is now responsible for the entire research programmes on potato in the country.

Structure

The institute has a total sanctioned scientific strength of 107 under taking research under six Divisions, viz. Crop Improvement, Crop Production, Plant Protection, Crop Physiology, Biochemistry and Post-Harvest Technology, Seed Technology and Social Sciences through 17 multi-disciplinary research programmes (now curtailed to 10) and equal number of externally funded projects. The institute has 7 regional research stations located in different potato growing areas of the country viz. Kufri-Fagu (HP), Modipuram (UP), Jalandhar (Punjab), Gwalior (MP), Patna (Bihar), Shillong (Meghalaya), and Ootacamund (Tamil Nadu). The institute has about 521 ha of farm area distributed over 15 units.

AICRP

The All India Coordinated Research Project on Potato (AICRP-Potato), located at the institute headquarters has been functioning since the fourth five-year plan. At the time of initiation in 1971, it had 9 centers, out of which two were CPRI based and seven were SAU based. Presently, it has a nation-wide network of 25 centers located at different agro-climatic regions of the country. Seven of these centers are located at the regional stations of CPRI while 17 are situated at different State Agriculture Universities (SAUs) and one voluntary centre is working at Ranichauri in Uttranchal. CPRI & AICRP (Potato), together carry out more than 95% of potato research in the country. The remaining

5% R&D activities are undertaken by other universities and research institutes within and outside the ICAR system.

Vision

Potato for food and nutritional security and sustainable inclusive growth

Mission

Carry out research on potato in collaboration with national and international partners for enhancing productivity and profitability, achieving sustainable food and nutritional security, and alleviating rural poverty.

Mandate

CPRI: The research and development agenda of CPRI is primarily guided by the following mandate.

- To undertake basic and strategic research for developing technologies to enhance productivity and utilization of the potato.
- To produce disease-free basic seed of different notified varieties developed by the Institute.
- To act as a national repository of scientific information relevant to potato.
- To provide leadership and coordinate network research with state agricultural universities for generating location and variety-specific technologies and for solving area specific chronic problems of potato production.
- To collaborate with national and international agencies in achieving the above objectives.
- To act as a centre for training in research methodologies and technology for upgrading scientific manpower in modern technologies for the potato production.
- To provide consultancy in potato research and development.

AICRP (Potato): All India Coordinated Project (Potato) has important role to play under the following mandate.

- Coordination and monitoring of multi-location trials for evaluation of improved potato hybrids and to standardize agronomic practices related to crop production vis-à-vis identification of remunerative potato based cropping systems, plant protection measures and post harvest technology, in order to facilitate enhancement in potato production, productivity and utilization in the country.

- Linkage between different stakeholders connected with potato production and utilization.

Available R&D infrastructure

CPRI is equipped with modern facilities to carry out basic and strategic research on all aspects of potato. The state-of-the-art biotechnology laboratory of the institute was created in 1992 and presently it has all the facilities for transgenic research, DNA fingerprinting, molecular breeding, micro-propagation and *in vitro* conservation. A new laboratory has recently been created for conducting basic research on cell biology and somatic cell genetics. To facilitate high throughput genome sequencing and functional genomics, a Genome Laboratory with modern facilities has also been created. The virus diagnosis laboratory of the CPRI is equipped with automated ELISA system, PCR and NASH facilities. Because of its unique record in the field of virus diagnosis, this laboratory has been notified by the Government of India as 'Accredited Test Laboratory' for testing and certification of tissue culture raised potato microplants and minitubers. The institute also has aeroponics facility for rapid multiplication of quality planting material.

Transmission Electron Microscope (TEM) is the latest addition at CPRI for detection and diagnosis of major potato viruses. CPRI possesses a world class potato library at its headquarters having 35164 documents including 13545 books and 14368 back volumes of research

TEM/Sequence

journals serial publications 2446 and 213 current journals (60 foreign; 152 Indian). Various CD ROM database e.g. CABI further enrich its knowledge base. The library has been automated through local area network for providing 'at-the-desk' library services, in order to save the time of researchers. All regional centres of the institute also have small libraries. Availability of sufficient land is one of the important pre-requisites for agricultural R&D. CPRI possesses 521 ha of farm land which is used for the production of potato breeder seed and also for experimental purposes. The institute has been regularly maintaining and creating required supporting infrastructure like buildings, roads/paths, structures (glass/ poly houses) etc.

CPRI- An accredited Test Laboratory

The institute has been awarded National Accredited Test Laboratory for Certification of virus free and true to type tissue culture microplants of potato by the Department of Biotechnology, Government of India.

Major Achievements

During last 65 years of its existence, the institute developed need-based technologies that triggered a revolution in potato production on account of very fast growth in area and productivity. A few breakthrough technologies and major achievements of CPRI that helped in sustainable growth of the potato crop in India are listed below.

Crop Improvement

- Partnered with 26 international institutes belonging to 14 countries in deciphering the complex potato genome.
- Developed and released 50 potato varieties with different traits viz. late blight resistance, heat tolerance, processing quality (6 varieties), multiple resistances to diseases and increased yield.
- Developed & registered 17 improved breeding lines as elite genetic stocks having earliness, resistance to pest & disease and frost tolerance.
- Developed two interspecific somatic hybrids of potato *Solanumtuberosum* dihaploid C-13 (+) *S. etuberosum*, and C-13 (+) *S. pinnatisectum* resistant to Potato Virus Y and late blight through protoplast fusion to overcome the sexual barriers.
- A parental line having extreme resistance gene to PVY (*Ryadg*) in triplex state and two advanced hybrids (LBY-15 & LBY-17) having combined resistance to late blight and Potato Virus Y were developed through marker assisted breeding.

Multiple disease resistant varieties

Potato productivity in the developed world has almost stagnated during the last two decades largely due to yield losses by biotic and abiotic stresses. Future productivity threats posed by impending climate change and global warming are looming large on developing countries including India. Potato cultivars having multiple disease resistance are urgently required not only to maintain the existing potato yield levels but also to boost it further in order to bridge the gap between the potential and actual yield levels. Among biotic stresses, late blight, viruses and nematodes are the most devastating ones. Resistance genes for late blight, most of the potato viruses and potato cyst nematode have been mapped and tightly linked molecular markers are available to perform marker-assisted selection (MAS). Therefore the institute has clear roadmap for developing potato varieties with multiple disease resistant exploiting parents having different resistant genes through MAS.

- Developed transgenic potatoes with important agronomic traits viz., late blight durable resistance, reduction of cold induced sweetening, high protein content, resistance to Potato Virus Y, Potato Apical Leaf Curl Virus, Potato Tuber Moth, and altered plant architecture.
- Fourteen genes/promoters coding for important traits like tolerance to potato tuber moth, late blight, potato leaf roll virus, potato stem necrosis virus, starch quantity, reduction of cold-induced sweetening etc. were cloned for use in genetic transformation studies without any IPR obligation.
- Identified potato genotypes having multiple resistance genes for Late Blight (R1&R3), Potato Virus Y (Ryadg) & Cyst Nematodes (HC, H1&Gro1) using molecular markers.

Plant Protection

- Developed late blight forecasting models for hills and plains.
- Developed and standardised virus detection and diagnostic techniques including dipstick assay for all important viruses.
- Replaced hazardous organomercurials chemical with the safe boric acid (3%) in seed treatment to check soil and tuber borne diseases particularly black scurf and common scab.
- Developed IPM for management of all important diseases and pests.

IT, GIS and Remote Sensing

- Developed potato crop growth model "INFOCROP-POTATO" to enable estimation of yield gaps and develop best management practices (BMPs).

Late blight forecasting

The institute developed JHULSACAST- a computerized late blight forecasting model for Uttar Pradesh. It predicts late blight disease 10 days in advance thereby helping the potato growers in protecting their crop by applying fungicides pro-phylactically. This model has also been calibrated for Punjab, Tarai region of Uttarakhand and plains of West Bengal. Based on this model, a Decision Support System (DSS) has been developed for western Uttar Pradesh having three modules viz. i) decision rules for predicting first appearance of the disease ii) decision rules for need-based application of fungicides and, iii) regression models for yield loss assessment. This DSS is web-based and hosted on CPRI server (http://cpri.ernet.in/LBDSS/default.aspx).

Recently the Institute has developed INDO-BLIGHTCAST- a web based Pan-India model for forecasting potato late blight as an improvement over JHULSACAST. It predicts late blight appearance using daily mean temperature and RH data available with meteorological stations across the country without any calibration. The model is being operationalized throughout the country in collaboration with IMD.

- Developed a decision support system "Computer Aided Advisory System for Potato Crop Scheduling" (CAASPS) which helps to decide the time of planting/harvesting considering the expected yields of different varieties planted in different times in most of the potato growing regions of the country.
- A methodology for estimation of potato acreage and production in the northern Indo-Gangetic plains using crop modelling, remote sensing and GIS has been developed in collaboration with Space Applications Centre (ISRO), Ahmedabad.

Seed Technology

- Development of Seed Plot Technique which enabled seed potato production in sub-tropical plains.
- Annual production of about 30000 q breeder seed of about 25 commercial varieties to facilitate supply of quality potato planting material in the country.
- Developed aeroponic technique for production of healthy seed potato.

Crop Production

- Developed resource management strategies for major potato based cropping systems involving sequential and intercropping systems in different parts of the country to sustain the productivity of potato crop.
- Developed nutrient use efficient (NPK and water) potato variety Kufri Gaurav.
- Standardised fertigation system for potato which economises on water by 40-50% and fertilizer N, P and K by 25-30% in comparison to conventional furrow irrigation besides 20-30% increase in potato yield.

Social Sciences

- Carried out impact assessment of potato technologies to estimate socio-economic returns to research investments.
- Dissemination of potato technologies through various extension programmes was undertaken at CPRI in order to bridge yield gap across the country.

Storage Technology

- Developed elevated temperature and on-farm storage technologies for storing table and processing potatoes.

AICRP (Potato)

- Standardized the technique for commercial production of hybrid TPS under short day conditions in the plains.
- Identified optimum time of planting, seed rates and seed size for efficient use of resources and inputs in different regions of the country.
- Established fertilizer needs of potato crop in different agro-eco-regions.
- Identified remunerative potato-based cropping sequences in various parts of the country.
- Identified suitable varieties of potato, rice and wheat for introducing potato cultivation in the rice-wheat system and to bring more area under potato for enhancing its production in the country.
- Developed spray schedule using systemic and contact fungicides either alone or in combination for control of late blight on the popular potato varieties in north-western, north-eastern and the central plains.
- Standardized and recommended boric acid treatment against tuber borne diseases like common scab and black scurf to replace environmentally hazardous organo-mercurial compounds (OMCs).
- Standardized package for managing potato stem necrosis disease in warmer areas.

Challenges

First and foremost challenge before the institute is to enable the country to achieve potato production of 125 million t at an ACGR of 3.2% with the help of 34.51 t/ha productivity and 3.62 million ha area under the crop during 2050. Availability of additional agricultural area, fragmentation of land holdings, abiotic and biotic stresses are expected to pose serious constraints for the future growth of potato in India. Modelling research shows that problem of bacterial wilt, late blight, PTM and white flies will aggravate under the regime of climate change. Development of short duration and biotic stress resistant potato varieties will be employed to mitigate these constraints. The challenges in the way of achieving these targets and technological interventions in order to meet these challenges need to be addressed separately for different time horizons.

Short Term

Rising input prices and severe shortage of farm labour are posing very serious short term challenges for potato cultivation in India. Steady increment in the prices of potato's competing crops over last several years, such as wheat, sugarcane and other vegetables; have gradually lowered comparative profitability of this crop. Further, the input prices have been increasing steadily while the output prices are relatively stable affecting farm profitability adversely. Enhanced resistance of pests (both diseases and pests) to the chemicals in the past is another important issue to be addressed in the short run. Rising average night temperature and fog in several potato growing areas in the country is lowering already constrained productivity of potato due to limited sunshine hours and shorter crop duration. Lack of state of the art transport infrastructure adversely affects potato producers and consumers across the country due to its bulky nature and seasonal as well as regional concentration of production scenario. This deprivation is not only responsible for wider price differences in this agri-commodity across the regions but also high post-harvest losses. Shortage of cold storage capacity and also their functionality in some parts of the country has also negatively affected potato growth.

Comparative farm profitability studies will be conducted to explain these issues to policy makers. Enhancement of crop productivity

through more intensive and concerted efforts on dissemination of potato technologies to the end users will be used as a strategy to bridge yield gaps and to augment potato profitability of farmers. Improvement of seed potato quality will be achieved through state of the art diagnostics using transmission electron microscope, molecular techniques and dip-stick. Subsequently rapid in-vitro multiplication of planting material will be done using areoponics and other biotechnological techniques. Development of suitable potato machines for small and marginal farmers will be very high on the agenda of the institute. More than half of farm labour on mechanised farms is currently used for picking potato tubers. For large farmers, the institute will expedite the work of developing combine potato harvester performing digging and tubers lifting activities. Application of molecular techniques for better diagnostics and understanding the genetic makeup of potato pests in the recent past is likely to bring desirable results in the short term. After successful release of heat tolerant potato variety, Kufri Surya, CPRI is likely to release more such varieties to tackle the problem of heat stress in the short term. Gene(s) responsible for tuberisation will be identified in order to facilitate development of early maturity of potato.

Medium Term

Climate change, erratic precipitation and shortage of irrigation water would be important medium term challenges for potato cultivation in India. Creating supportive conditions for taking potato processing levels from the current 2.8 million tonne (including the processing at household, cottage industry and unorganised sector) to 6 million tonne (near 10% of anticipated potato production in the country) in the medium term is another challenge for the institute. Food security is likely to gain much higher importance in India in the medium term and potato will have to shoulder much heavier responsibility to address this impending challenge. As the future potato growth has to be led by productivity enhancement, increase in production potential and bridging yield gaps in spite of the impact of climate change on potato productivity per se and also due to its effect of higher biotic stresses.

Research efforts on development of micro-irrigation technologies for potato and their better dissemination in the regions with scarcity of irrigation water will be undertaken at CPRI. Development of improved processing varieties of potatoes under the ongoing breeding programme at the institute will help the nation raise potato processing levels. Enhancement of potato production potential in various parts of the country in light of heat and moisture stresses under climate

Precision farming

Precision farming as a tool of yield enhancement is ecologically better option and the institute will pay increased attention to such of technologies that offers enhanced resource use efficiency. The efficiency of production resources is enhanced by providing precise quantities of the inputs to the crops in right compositions. In the initial phase the institute will focus on precise application of inputs based on weather, soil and crop requirements to maximize productivity, quality and profitability in a more sustainable way.

change regime and national food security will be addressed through the exploitation of biotechnological and molecular breeding and plant protection techniques. In order to achieve higher harvest index from crop plant dwarf potato genotypes will also be developed using molecular techniques for cultivation under long photoperiod and or high temperature. Raising potato production efficiency will be achieved with the help of modelling research, precision farming, nanotechnology and improved mechanisation. Augmentation of seed potato quality and dissemination of technical knowhow to various stakeholders will be targeted through appropriate means in order to raise the crop productivity.

Long Term

Most of the medium term challenges are expected to extend in long term too. In fact some of the challenges like climate change and its adverse impacts are expected to aggravate further. Over next 40 years 465 million people will be added to our existing 375 million urban population (NCAP estimates) which will generate a huge demand for processed potato products. The industry has to be supported by the required technologies including the need for improved processing varieties in order to enhance potato processing up to 25 million t by the year 2050. Food security of 1619 million people will really be a tough challenge after 40 years. Increasing production potential of potato under the era of enhanced biotic and abiotic stresses to potato crop under global warming and climate change scenario is another complicated challenge before us in the long term. Dissemination of refined potato technologies to a very large number of small and marginal farmers in India is a challenge of its own type in India.

Efficient input (fertilizers, pesticides and irrigation etc.) delivery system and more accurate diagnosis of diseases using nano-science widely across the country will be one of the solutions for tackling the challenges of food security and enhancement of production potential in next 40

years. CPRI has already initiated concerted efforts in this direction. Use of biotechnological and molecular techniques to develop potato varieties with higher yield potential and resistance to diseases and pests will be another solution for this problem. Identifying yield enhancing traits through modelling research, manipulating crop geometry and developing ideotypes will also be employed. Development of drought and heat tolerant potato varieties will play crucial role in the future of Indian potato industry. Precision farming and improved mechanisation (e.g. automatic potato harvester, grader and bag filler) will be used to enhance potato farm profitability. Advanced information technology based dissemination (e.g. on mobile phones and through decision support/expert systems) of refined scientific potato technologies will be utilized.

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Demand Outlook

Potato is a predominant vegetable in India. At present most of the domestic supply of potatoes is consumed as fresh (68%) followed by processing (7.5%) and seed (8.5%). The rest 16% potatoes are wasted due to post harvest losses. However, the proportion of potato used/ wasted due to various reasons is expected to change in the medium and long term scenario.

Fresh Potatoes

Per capita consumption of fresh potatoes (FAOSTAT) increased from 1991 to 2010 at an ACGR of 2.34. Will this consumption rise in the future at the same rate? The stagnating growth rates of cereals' productivity, large scale diversion of food grains to feed & bio-fuel and expected steep rise in per capita consumption of pulses, edible oil, fruits, vegetables, milk, sugar and non-vegetarian food in the regime of steadily rising population is bound to put pressure on existing cultivable land. Since, cultivable land is expected to remain more or less constant in the next 40 years, the role of crops like potato having higher production potential per unit land and time will become imperative. In this context potato crop has very high probability of making crucial contribution to the future national food security agenda.

The perceived changes in Indian socio-economics in the medium and long term are expected to enhance per capita food consumption of fresh potatoes. Potato is an important ingredient of most of the fast foods in organised as well as unorganised sector. Rapid urban population growth from 375 to 840 million over next 40 years at an ACGR of 2.04% is expected against the overall national ACGR of population at 0.78%. Faster rise of number of nuclear families, higher disposable incomes on account of fast economic growth resulting into higher tendency of out-of-home eating and rapid increase in the number of working women in the medium and long run are expected to maintain the overall ACGR of 2.265% in per capita consumption of fresh potatoes. Per capita food demand of fresh potatoes at this ACGR will be 48.5 kg in the long term (Table 1). The corresponding national food demand for fresh potatoes will be 78.5 million t in 2050.

Processing Quality Potatoes

Agri-processing sector experiences very fast growth rate when an

Table 1 Per capita and total national food demand for fresh potatoes

Items	2010	2020	2030	2040	2050
Per capita fresh (kg)	19.78	23.70	29.16	37.12	48.47
National demand (million t)	23.94	30.84	40.82	55.89	78.47

economy transforms from developing to developed economy. The rise of Indian economy from $ 1.57 to between 13 and 34 trillion (under varied scenarios; NCAP estimates) is not possible without corresponding rise in agri-processing industry. Further, potato is always the front-runner when we take processing of agri-commodities into consideration. Analysis of past experience and pattern of Indian processing industry suggests that demand for processing quality potatoes over next 40 years will rise at the fastest pace for French fries (11.6% ACGR) followed by potato flakes/powder (7.6%) and potato chips (4.5%). The actual demand for processing potatoes will rise from 2.8 million t in 2010 to 25 million t during the year 2050 at an ACGR of 5.61% (Table 2).

Table 2 Raw material demand of potato processing industry (million t)

Product(s)	2010	2020	2030	2040	2050
Potato chips	2.45	5.59	9.09	12.06	14.22
Potato flakes/powder	0.29	0.89	1.99	3.58	5.44
Frozen potato products	0.06	0.30	1.03	2.64	5.40
Total	2.80	6.78	12.11	18.28	25.06

Potato starch making industry doesn't exist in India and its future is difficult to predict on account of short duration domestic potato cultivation, unknown future developments in potato starch industry of China and European Union (predominant global players) and possible allocation of more and more cultivable land to food security options rather than industrial products. However, if some quantity of potatoes is used for making potato starch or other industrial products, then this demand is not quantified and will be over and above the estimated one.

The corresponding total and per capita demand of actual processed potato products at current level and in the future is depicted in table 3. The total demand of processed potato products is estimated to rise from 0.7 million t in 2010 to 7.3 million t in 2050. The corresponding per capita demand for processed potato products will increase from 0.6 to 4.5 kg (6.03% ACGR) over the period of 40 years.

Seed Potatoes

As per FAOSTAT, India used 2.96 million t potato tubers (8.5% of

Table 3 Demand of potato products (thousand t)

		Potato Chips	Potato flakes/ powder	Frozen potato products	Total
2010	Thousand t	612	52	34	698
	Per capita g	506	43	28	577
2020	Thousand t	1398	160	168	1726
	Per capita g	1080	124	130	1334
2030	Thousand t	2273	358	556	3187
	Per capita g	1630	257	399	2286
2040	Thousand t	3015	644	1412	5071
	Per capita g	2007	429	940	3376
2050	Thousand t	3555	979	2808	7342
	Per capita g	2194	604	1733	4532

national potato production) as seed during triennium ending year 2010. The absolute quantity of potatoes used as seed is estimated to increase to 6.1 million t during 2050. However the proportion of tubers used as seed will fall to 5% of national potato production during 2050, on account of anticipated higher potato productivity.

Post-harvest Losses

At present a higher proportion of potatoes (16%) is wasted as post-harvest losses (PHLs) than that used as seed (8.5%) or processing (7.5%). This is an unfortunate situation that nearly 1 million t in excess to the total potato production in Canada during the triennium ending 2010 (FAOSTAT) was wasted in India. Although, due to hot summer temperatures, lack of state of the art cold storage facilities and massive transportation of potatoes from northern to southern states are the causes of the high wastage of potato in absolute terms, the proportion of PHLs to the total potato production in the country are targeted to be lower. The estimated PHLs are targeted to lower from the current 15.75 to 10% in the year 2050, while the corresponding quantity of PHLs is estimated at about 5.5 (current), and 12 million t (in 2050).

Export

Net annual average of Indian potato export over previous decade has more or less stagnated at 0.1 million t. Potato being semi-perishable and bulky agri-commodity, its export from India is not guided by a long term policy support. As potato is a politically sensitive crop, targeted steps are taken to keep its retail prices at affordable level for the ordinary consumer. Export is generally a crisis management tool during the years of oversupply. However, in international markets exports can

only be increased through building credibility and making long term contracts. It is anticipated that the future food policy will concentrate more and more on ensuring national food security and low value export of agri-commodities may be discouraged. Under these circumstances steep rise in export of fresh potatoes from the country is unlikely. India being the massive producer of potatoes a healthy growth in processed potato products is anticipated. However, unknown and complex future developments at international level are difficult to be assessed. Moreover, in the absence of a clear cut support through a robust export policy it is not possible to estimate and assign future targets for the export of processed potato products.

Other Uses

Currently we don't feed potatoes to animals hence no estimate can be generated on this use in the future. However, if some quantity of potatoes is used as animal feed then it would be over and above the estimated overall demand.

Total Potato Demand

The demand for potatoes in India is estimated to rise to 122 million t in the year 2050. Demand for processing quality potatoes will rise at the highest rate and their proportion in the net domestic supply will rise from 7.5% in the triennium ending 2010 average to 20.5% in 2050 (Table 4). Considering net domestic supply the proportion of potatoes

Table 4 Component wise potato demand (million t)

Year	Demand$	Fresh	Processing	Seed	Waste
2010	35.23	23.94	2.8	2.96	5.53
	(100	(68.21	(7.61	(8.43	(15.75
2020	47.91	30.84	6.78	3.55	6.74
	(100	(64.37	(14.15	(7.41	(14.07
2030	65.39	40.82	12.11	4.25	8.21
	(100	(62.43	(18.52	(6.5	(12.56
2040	89.26	55.89	18.28	5.09	10
	(100	(62.61	(20.48	(5.7	(11.2
2050	121.81	78.47	25.06	6.1	12.18
	(100	(64.42	(20.57	(5.01	(10

Note: Figures in parenthesis are percentages; $: net domestic demand

put to seed and wastage due to post-harvest losses will gradually decrease in future. Sharp increase in potato utilization for processing purpose will slightly lower down the proportion of fresh potato consumption as food by 2050. ❑

Operating Environment

After putting 46% of total area under agriculture, India is seriously constrained as far as bringing more land under agriculture is concerned. On the contrary we are already doing agriculture on marginal and degraded lands. Rising population and resulting fragmentation of land holdings has created a situation where farming doesn't generate complete livelihood for majority of the farmers, including the potato farmers. Resultantly, the farmers are not practicing agriculture professionally following the recommended scientific package of practices. This peculiar situation creates task of technology transfer quite tough and challenging.

Climate change scenario is supposed to adversely affect potato production and productivity in India. Modelling research at CPRI suggests that by the year 2020 potato yield is estimated to fall by 19.65% in the state of Karnataka followed by Gujarat (18.23% fall) and Maharashtra (13.02% fall) with an overall fall of 9.56% at national level if needed steps are not taken to mitigate the effects of climate change. The situation is expected to further worsen by the year 2050 when the national level potato production is expected to fall by 16% in the absence of needed steps. However, the potato production fall may be much severer in the states of Karnataka (45% fall), Gujarat (32% fall), Maharashtra (24.5% fall) and Madhya Pradesh (16.5% fall) if preventive steps are not taken.

Potato growth in India has largely been uneven as nearly 85% potato in the country is produced in North Indian plains. Average potato productivity in India is more than 20 t/ha in states like Gujarat, Punjab, Uttar Pradesh, Haryana and West Bengal while several states in hills and plateau region have yield less than 10 t/ha (Maharashtra, all North eastern states, Sikkim and Karnataka). About 95% of the national potato is harvested in Rabi season. The regional and seasonal production of potato is largely responsible for price fluctuation in this agri-commodity. About 90% of disease free seed potato is produced in Punjab, specially the Jalandhar district, which makes several potato producing areas in the country quite distant, from seed potato marketing angle.

Crop husbandry is affected by the latest developments in other related fields to a great extent. Such developments have taken place at a fast pace during the recent past and consequently the farming conditions

are also changing to an equal extent. Contract farming is one of the new concepts of current nature in Indian context which is extensively used in potato farming (Singh et al., 2011). This concept is much preferred by the potato processing industry in order to have higher certainty and control over raw material supply chain i.e. processing grade potatoes. The concept is equally favoured by seed potato producing companies. The contract farming route to procure desirable produce is also exploited by retail chains for specific quality potato material. Crop insurance is another area that affects potato farmers to a great extent. However, this concept is still to attain the desired maturity. Future trading of agri-commodities is another development of recent past in India and it is still ill-understood by most of our farmers. However, its effective utilization provides a potent price risk management tool to the producers. Need of mechanization due to the shortage of farm labour and higher importance of efficient inputs delivery system are gaining increased attention of potato farmers in India.

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Opportunities & Strengths

Varied climatic conditions across the country provide opportunity of round the year potato production in India. The advantage has been thoroughly exploited by potato processing industry for round the year supply of raw material and seed potato producers for taking double crop to ensure faster multiplication. However, the country still has tremendous scope of further progress in this direction.

At present 1210 million people of India consume potato mainly as vegetable. However a population of much richer 1619 million people (NCAP estimates) during 2050, out of which more than 840 million being urban (against the current 375 million) and much higher proportion of working women and nuclear families, will totally transform the demographic structure of India. Incidentally this change will be conducive for higher demand for potato (as vegetables and fast food ingredients) and processed potato products in the future. Fast increment in per capita as well as total household consumption of potato in India during recent past is expected to sustain in the foreseeable future hence; there is great potential of enhancing potato production in the country. The gradual shift of potato cultivation from developed nations to the developing ones provides great scope of potato exports in the future for countries like India.

Strong existing potato research and development base and adequate preparedness for future challenges is expected to provide requisite support to the future needs of potato industry in India. Application of new science in the fields of bio-technology, nanotechnology, genomics, phenomics, diagnostics, precision farming, aeroponics, ICT, GIS and remote sensing has already been successfully demonstrated by the CPRI. We expect these areas to serve the cause of future potato R&D in a big way. The available physical and scientific infrastructure at CPRI is enough for not only further accelerating potato R&D momentum at national level but also for emerging as a leading global player, especially in the tropics and subtropics. However, sustained efforts will be made to upgrade these facilities and pursue rigorous human resource development at the institute level.

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Goals and Targets

After accounting for rapid growth of potato processing due to estimated fast economic development of India, lower proportionate requirement for seed (due to higher productivity), rise in per capita consumption of fresh potato (rapid urbanisation, future role of potato in food security and fast economic development) and as a result of ongoing efforts to lower proportionate PHLs, the estimated demand of potatoes in 2050 would be about 122 million t. However, making provisions for un-estimated demand for future for other industrial uses, animal feed and expanded exports etc. the total demand of Indian potato is expected to be 125 million t(Table 5). The WOFOST model estimates that potato yield during 2050 would be 34.51 t/ha, and in order to meet demand for Indian potatoes we would need 3.62 million ha of area under the crop. In order to meet the said targets the estimated potato yield in years 2020, 2030 and 2040 is 22.37, 25.8 and 29.83 t/ha, respectively. Increased emphasis on breeding short duration potato varieties (in order to fit in between rice and wheat) and area adjustment under the influence of relative profitability as dictated by the price (demand and supply) scenario are expected to achieve this additional area in the situation of rather scarce cultivable land in India.

Table 5 Potato production, productivity and area estimates for 2050.

Particulars	Area million ha	Production million t	Productivity t/ha
2010	1.83	36.58	19.93
2020	2.16	48.25	22.37
2030	2.56	66.11	25.80
2040	3.04	90.59	29.83
2050	3.62	124.88	34.51

Environmental Safety

CPRI has assigned very high priority to the efficient delivery of inputs in its future R&D agenda in the form of precision management of nutrients (including the secondary nutrients) and water (micro irrigation). Balanced and efficient fertilizer use has to be supplemented with increasing soil organic matter contents through soil carbon sequestration supported by incorporation of crop residues, green manuring, application of FYM, compost, vermi-compost, bio-fertilizers and other bio-digested products. ❑

Way Forward

Future Road Map of CPRI

In future, potato has to emerge from just a vegetable to serious food security option. Considering limited availability of cultivable land in the country higher potato production has to be led by growth in productivity. Future roadmap of potato R&D at CPRI would be primarily focused on enhancing potato productivity to 34.51 t/ha by the year 2050. The second focus of the institute will be to improve quality of potato as desired by the industry as well as potato consumers in the era of economic development, higher purchasing power and willingness to pay more for the desired quality. Research on improved potato storage will be targeted as another vital component in order to lower post-harvest losses during the next 40 years.

Strategy for achieving targets

In order to meet targets and tackle anticipated challenges, following seven-pronged strategy would be employed to accomplish the goals set in the vision.

1. **Effective exploitation of genetic resources for varietal improvement**
   - Molecular characterization and development of core collection of the germplasm.

Pre-breeding and genetic enhancement of potato

Wild Solanum species are a rich source of diversity for various biotic or abiotic stresses, and desirable agronomic traits which still remain untapped. For broadening genetic base of cultivated potato, it is urgently needed that the genetic potential of these wild species is harnessed to enhance potato production in order to address the food security issues in a sustainable way. International collaborations are required in terms of utilization of wild germplasm for conservation and sustainable use of wild species, access to wild species genetic diversity, gene mining activities by genomics tools, systematic and integrated strategy for evaluation, characterization of a range of traits, population development, and use of molecular/genomics tools for potato improvement.

Therefore, pre-breeding research at CPRI would be mainly focused towards acquisition of wild species from international gene-banks, evaluation of those wild species for various desirable traits, development of elite genetic stocks by somatic hybridization and 2n gametes fusion, mapping population for selected traits, core collection and linked molecular markers leading to break yield barriers in potato.

- Development of mapping population and pre-breeding including somatic hybrids for exploiting wider gene pool.
- Heterosis and hybrid vigour leading to enhancement in production potential of potato.

Hybrid Potato

Although all potato varieties developed worldwide are hybrids but hybrid vigour/heterosis is not harnessed to its fullest potential as the parental lines are not in-breds/pure lines. True potato seeds (TPS) produced sexually holds a great promise for growing potato from botanical seeds instead of tubers. Almost all viruses are unable to infect TPS with desirable escape from deterioration of seed quality. One of the problems with breeding potato varieties which can be propagated and grown from true seed is lack of uniformity in agronomic traits. The heterogeneous nature of TPS is due to the heterozygous nature of parents. Pure lines/in-bred parental lines cannot be produced in potato due to high inbreeding depression & self-incompatibility. In semi-cultivated potato, the self-incompatibility inhibitor gene (Sle) is known. This gene can be edited in cultivated potato by CASPER-CAs techniques for producing trait specific homozygous parents for harnessing hybrid vigour.

- Development of potato varieties and populations for short duration, processing, starch making, heat & drought tolerance, biotic stress tolerance, nutrient use efficiency, *kharif* season, exports, early bulking, and TPS populations.

2. Safe application of biotechnology for potato improvement

- Structural genomics and bioinformatics for developing robust molecular markers for qualitative and quantitative traits.
- Functional genomics for gene discovery for targeted traits like late blight durable resistance, heat tolerance, high temperature tuberization, better water and nutrient use efficiency.
- Proteomics and metabolomics for basic studies on tuberization, photosynthesis, partitioning of photo-assimilates, starch metabolism, carotenoid and flavonoid synthesis, storage protein quality, processing quality.
- Technology development for marker-free and site-specific integration of transgenes.
- Development of transgenic potato with improved resistance/ tolerance to biotic/abiotic stresses and to improve nutritional and processing quality.

3. Encouraging production of quality planting material

- Development & standardization of low cost and efficient mass propagation methods – aeroponics, bio-reactor technology.

Breeders seed production

Currently CPRI produces about 30,000 quintals nucleus and breeder seed every year which is only sufficient to meet the demand of healthy seed potato in the country. However, keeping in view the production of 125 million tonne of potatoes from 3.62 million ha by 2050, this supply of breeder's seed is likely to fall short of the demand. CPRI targets to produce nucleus and breeder seed during 2020, 2030, 2040 and 2050 equal to 33,000, 36,000, 39,000 and 42,000 quintals, respectively. As there is limited scope to increase quantity of breeder seed at CPRI farms due to limitation of additional availability of land for seed production therefore, collaborations with other government organizations e.g. SAUs is being explored.

- Vector dynamics and its implications on seed quality.
- Development of homozygous TPS populations using apomixes and monohaploidy.

4. Resource based planning and crop management

- Development of IT based Decision Support Systems/tools for crop scheduling and management of weeds, nutrients, water, diseases and pest sunder climate change scenario.
- Standardization of technologies leading to improved carbon sequestration and soil health.
- Development of technologies for enhancing inputs use efficiency through precision farming and micro-irrigation.

Micro-irrigation in potato

Micro-irrigation (drip and sprinkler) enables high frequency application of water in and around root zone of the plants. This system is useful for fertilizer and pesticides application resulting in efficient use of production inputs. Potato has a sparse and shallow root system and nearly 70% of total water is used by the crop from upper 30 cm soil layer. It requires 400-600 mm of irrigation water depending on climatic conditions, soil type, length of growing season, duration of variety, purpose of crop and methods of irrigation etc. The CPRI has developed technology of micro-irrigation for use in potato crop. Through fertigation nutrients are applied with irrigation (drip) near the root zone of the plants for providing optimum moisture and nutrients throughout the crop growth period. Sprinkler fertigation is also a new technique where nutrient particularly nitrogen is applied through sprinkler by foliar spray directly to the foliage.These methods of irrigation/fertigation economise on water (about 30-50% saving) at the same time giving 15-30 higher yield with upto 25% saving on fertilizers. The technology has been adopted by potato farmers in different parts of the country, however, Gujarat may be considered a role model for adoption of modern methods of irrigation as the state has the highest adoption of micro-irrigation technology including in potato crop. Consequently Gujarat has the highest potato productivity in India.

5. **Eco-friendly crop protection**
   - Cataloguing genome variability and dynamics of new pathogen/ pests populations (Pathogenomics).
   - Development of diagnostics for detection of pathogens both at laboratory & field level using micro-array and nano-technologies.
   - Ecology and management of beneficial microorganisms for enhancing crop productivity and disease management.

Portable dipstick kits

The institute developed portable dipstick kits for field level detection of major potato viruses based on lateral flow immuno assay for single or a combination of two viruses. These kits are portable and easy to use by any stakeholder including farmers at field level for ascertaining health standard of the potato crop. The kits were released by Hon'ble Minister of Agriculture on Foundation day of ICAR after having been validated at AICRP (P) centres and by the progressive growers.

6. **Encouraging energy efficient storage and diversified utilization of potato**
   - Technology refinement for elevated temperature storage for both on- and off-farm situation.
   - Development of new processes, products and utilization technologies for diversified use of potatoes including waste utilization.
   - Food fortification to enhance nutritional quality of processed foods.
   - Technologies for lowering glycemic index.
7. **Strengthening institute-farmer interface for technology dissemination**
   - Comparative farm profitability studies vis-a-vis ability to contribute to GDP by various crops, for providing efficient policy input.
   - Proficient technical dissemination through an optimal mix of traditional and modern extension tools.

Cutting Edge Research Themes

CPRI will use following cutting edge research themes for its future R&D agenda.

- Development of transgenic potatoes to address high risk areas viz. biotic and abiotic stresses, quality enhancement and wider adaptation.

Early maturing day neutral varieties

Future emphasis of the institute would be on exploiting technologies like genomics, transcriptomics and other-omics in the field of potato improvement. The genes and alleles are known for tuberization and maturity and therefore, in the near future it will be very well be endevoured to develop varieties that mature in 50-60 days and capable of being fitted in various crop sequences.

- Processing sector: development of cold chipping varieties.
- Seed sector: production of seed potatoes in non-traditional areas.
- Health sector: development of potatoes with low glycaemic index and high antioxidant contents.
- Identification of new genes and markers for important traits.
- Fully automatic potato harvester to economize on labour.
- Studies on potato proteomics and phenomics with reference to tuberization.
- The next generation molecular marker, SNP, with reference to disease resistance and quality traits, will be developed by allele mining and resequencing.
- Bio-risk intelligent system (surveillance of racial pattern of different pathogens and pests and early warning systems) would be developed for taking informed decision at the local, regional and national levels.
- ICT, GIS and remote sensing options will be used to understand and mitigate ill effects of climate change & global warming, identify new potato growing areas and to develop decision support systems to meet impending complex challenges.

Relevance of CPRI by 2050

Under the influence of rapid privatization and disinvestment of government run institutions, it is obvious to think whether government sector institutes like CPRI will remain relevant by 2050 or not? The answer is not simple and straight forward. It is sure that such institutes will have to depend heavily on self-generated resources through private collaborations, consultancy projects and delivering customised solutions for their very survival. CPRI has already started commercialization of its technologies like aeroponics and bio fertilizers (B-5) etc. The extra-ordinary ability of the institute to quickly respond and adjust to the new situation makes it a fit candidate not only to survive by 2050 but the institute is expected to emerge as a centre of excellence in potato R&D at global level by that time.

CPRI has enough preparedness, not only to retain its position as a

premier potato R&D organisation of the country, but also to emerge as leading global research establishment. This confidence is not just out of the wishful thinking, but based upon the world class facilities created at the institute with the hard work of several years. By being the Indian member of the consortium of 26 international institutes belonging to 14 countries for deciphering potato genome and by publishing the output in the globally leading scientific publication 'Nature', CPRI has already commenced its journey towards this destination. By the year 2050 CPRI would not be just a contributing partner in the multinational potato research projects but it would act as research leader for global potato R&D, especially the tropics and sub-tropics.

Aeroponic

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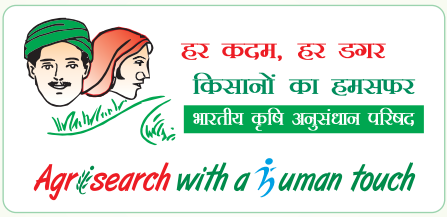
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