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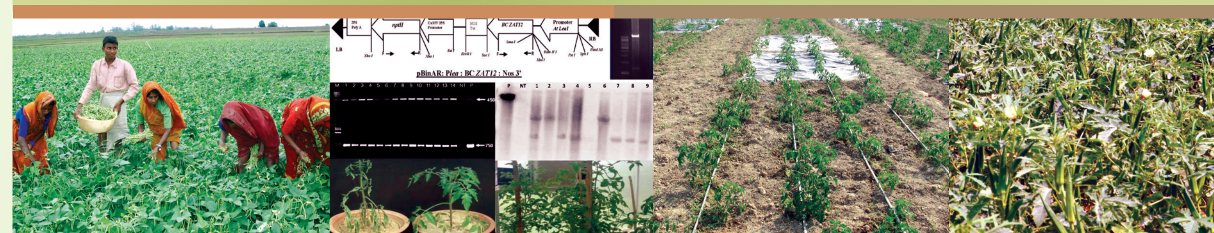
Vision 2050



भाकृअनुप
ICAR

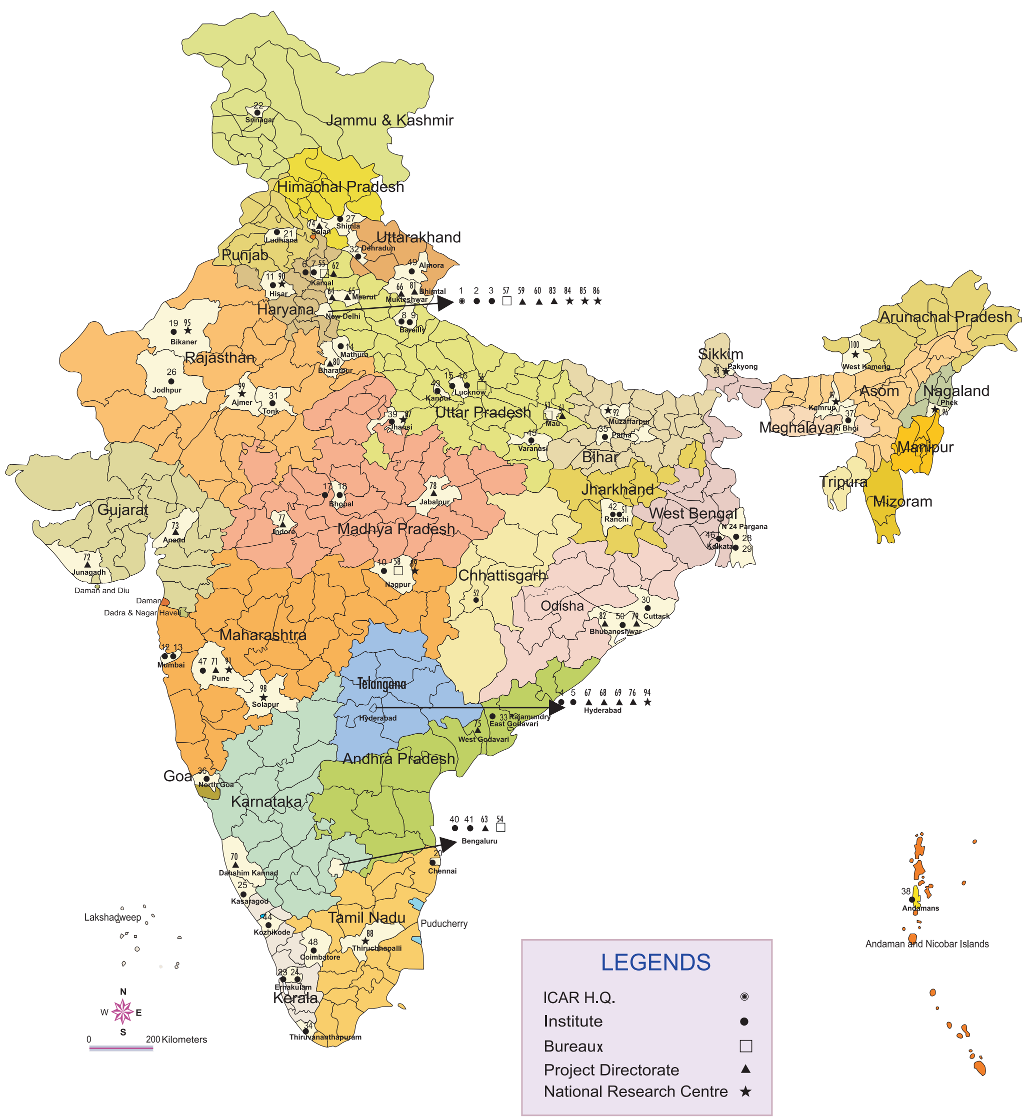
Indian Institute of Vegetable Research

Indian Council of Agricultural Research

INDIAN INSTITUTE OF VEGETABLE 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

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Agricultural Universities

LEGENDS

- State Agricultural Universities ○
- Central Universities with Agricultural faculties ■
- Central Agricultural Universities ☆
- Deemed Universities ●

Vision 2050

Indian Institute of Vegetable Research

(Indian Council of Agricultural Research)

Varanasi 221 305

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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-Indian Institute of Vegetable Research (IIVR), Varanasi 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)
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Preface

Vegetables are important constituents of Indian agriculture and nutritional security. Diverse agro climatic conditions of India permit to grow more than 60 cultivated and about 30 lesser known vegetable crops. Systematic research efforts backed by developmental activities and policies have resulted in development of numerous improved varieties/ hybrids and production technologies resulting in phenomenal increase in area, productivity and production of vegetables during the last 6 decades. Increasing population, *per capita* income, health consciousness, urbanization, and working women are responsible for increasing demand for nutritionally rich foods in the country. High returns, favourable income elasticity of demand and annual growth rate for domestic demand are also important catalysts for attracting farmers to vegetable cultivation and promoting its growth. However, the spectacular growth of vegetable production has accompanied with several issues like low or uneven productivity across the country; perishability and high cost of cultivation; inadequate varieties and ecofriendly agro-techniques for improving total factor productivity (TFP), export, processing, organic and protected cultivation; inadequate and delayed availability of planting material of improved varieties; poor quality of the produce including food safety issues like pesticide residues, microbial contamination, colouring agents etc.; uneven technological empowerment of farm workers; inadequate infrastructure for storage, transportation, marketing and export; and minuscule value addition and export. These issues need to be addressed under scarcity of natural resources; emerging biotic stresses; environmental concerns; WTO and IPR issues; low investment in R & D.; diversion of workforce from rural to urban areas; climatic change and competition from other crops.

Vision 2050 document of the ICAR-Indian Institute of Vegetable Research contains systematic research road map for production of 375 million tons vegetables from 15 ha area at 25 t/ha productivity with innovation driven technologies that are technologically sound, resource sustainable, economically viable, socially acceptable and environment friendly. The vision also envisages ensuring recommended *per capita* availability of vegetables (300 g) to usher nutritional security in the country, reduction in postharvest losses and enhancement of value addition and export.

Dr. N.K. Krishna Kumar, Deputy Director General (Horticultural Science), ICAR has always been a motivating and guiding force behind setting future research priorities for the IIVR. I would be failing in my duties if I do not acknowledge his extraordinary interest and guidance. I sincerely acknowledge efforts of the scientists of this Institute for providing inputs for preparation of this document. I believe the document will provide precise direction and focus to the current and future vegetable research in the country.

B. Singh
Director
ICAR-Indian Institute of Vegetable Research
Varanasi

Contents

Context

Vegetables are important constituents of Indian diet and play an important role in ensuring nutritional security to the burgeoning Indian population. They are generally of short duration, high yielding, nutritionally rich, economically viable and generating on-farm and off-farm employment. It also have a pristine place in Indian agricultural economy. Being blessed with diverse agro climatic conditions ranged from the temperate to arid, more than 60 cultivated and about 30 lesser known vegetables are being grown in India.

The country has witnessed a tremendous increase in vegetable production and productivity as a result of development of improved vegetable varieties/F_1 hybrids/technologies through systematic research coupled with their large scale adoption by the farmers and developmental policies of the government. Compared to area (2.84 m ha), production (16.5 mt) and productivity (5.8 t/ha) in 1950-51, there had been phenomenal increase in area (3.2 folds), production (9.83 folds), productivity (3.38 folds) and *per capita* availability (2.85 fold) of vegetables in our country during the last 6 decades (Figure 1). Increasing *per capita* income, health consciousness, urbanization, increasing number

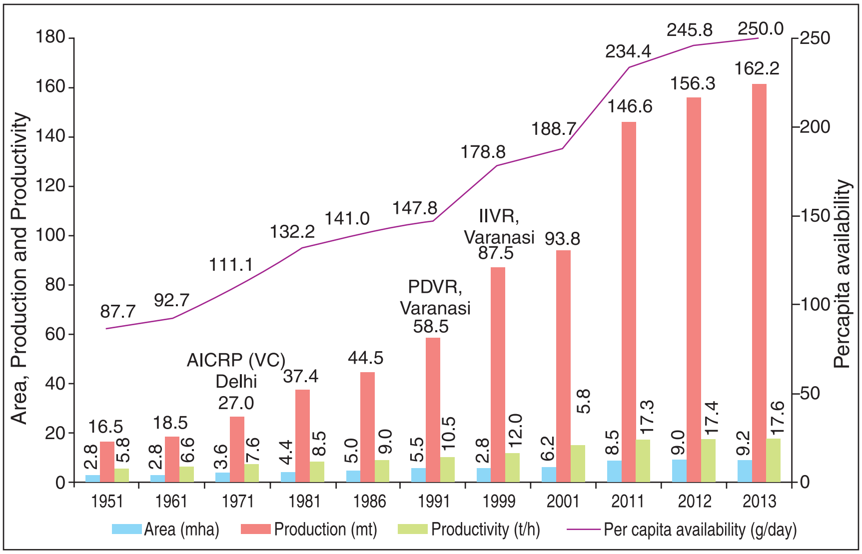

Fig. 1 Area, production, productivity and *per capita* availability of vegetables in India.

of working women, shifting of farmers to high value vegetables due to higher income, favourable income elasticity of demand and annual growth rate of domestic demand for vegetables are also important factors for fuelling its growth in the country.

Presently, China (573.9 mt), India (162.2 mt), USA (35.94 mt), Turkey (27.81 mt), and Iran (23.48 mt) are the major leader in vegetable production in world, contributing 49.5, 14.0, 3.1, 2.4 and 2.0 per cent of world production (NHB, 2013), respectively. India is the second largest producer of vegetables with the production of 162.6 mt from an area 9.2 m ha with average productivity of 17.6 t/ha in 2012-13. Tomato (11.3%), brinjal (8.1%), cabbage (5.3%), cauliflower (4.9%), okra (3.9 %) and pea (2.5%) are the five major vegetables, contributing 36.0% of total production in the country. In the world scenario, India ranks first in production of okra (72.9% of world production), second in brinjal (27.1%), cabbage (12.2%), cauliflower & broccoli (35.6%) and tomato (11.2%). Productivity of vegetable is highest in Spain (39.3 t/ha) while, India ranks 10^{th} in world average productivity, lower than and world average (19.7 t/ha).

In the country, West Bengal is the top vegetable growing state, cultivating vegetables over an area of 1.35 mha and producing 25.47 mt of vegetable followed by Uttar Pradesh (0.91 m ha, 19.57 mt), Bihar (0.86 m ha, 16.32 mt), Andhra Pradesh (0.69 mha, 12.10 mt), Gujarat (0.54 mha, 10.52 mt), Karnataka (0.43 m ha, 7.84 mt), and Tamil Nadu (0.28 m ha, 7.89 mt), respectively. There had been regional disparity in area, production and productivity of vegetables across the country. Analysis of state-level productivity in India reveals that Uttar Pradesh, Madhya Pradesh, Tamil Nadu, Punjab, Kerala, Jammu & Kashmir and Arunachal Pradesh are the states with productivity higher than the world average, whereas Rajasthan, Mizoram, Nagaland and Sikkim, it is below 10t/ha.

Horticulture plays an important role in India's economy accounting for about 30.7% of India's agricultural GDP from 13.7% of cropped area. Focused attentions to this sector in country's five year plans were given mainly from the VII plan period onwards. According to a World Bank report (2005) entitled as "From Competition At Home to Competing Abroad: A Case Study of India's Horticulture", India is a large, low cost agricultural producer; however, its share in global agricultural exports is minuscule.

During 2012-13, the total vegetable exports, including potato and onion, from India accounted for Rs 3482.96 crores, sharing 32.87% of total horticultural exports. The major vegetables exported from India are onion, tomato, peas, potato and cauliflower. UAE, Nepal, Sri Lanka, UK and Saudi Arabia are the major importers of our vegetables accounting for around 55% of the total vegetable exports. Though India is the second largest producer of vegetables in the world it ranks 24th in the export value. Netherlands is the largest exporter of vegetables in the world followed by Spain, Mexico, China and France. Non-harmonization of international quality standards, inadequate export infrastructure and export friendly policies are the major factors that need to be addressed for promoting export of vegetables from India.

The productivity of vegetable crops has been increasing during the last one decade as compared to other horticultural crops (Figure 2). This increase in productivity is in spite of the fact that plan schemes did not have substantial components supporting development of this crop segment. If India has to achieve 4% agricultural growth rate, the required growth rate in horticulture has to be 6-7%. Vegetables can contribute to rapid growth in initial period itself which can later on be supplemented by perennial fruit and plantation crops.

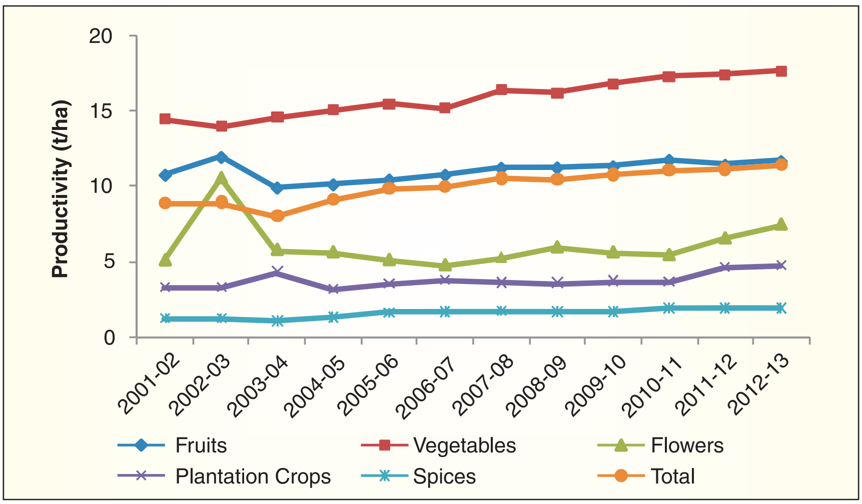

Fig. 2 Productivity trend of horticultural crops during the last decade

With current level of vegetable production in the country (162.2 million tons), population (1.27 billion) and considering 25% post-harvest losses and 5% export and processing, *per capita* availability of vegetables in our country is 250 g as against 300 g recommended dietary allowance (RDA). Thus, now also we have shortage of about 50 million tons of vegetables. With projected population of 1.33 billion in 2020, 1.46 billion in 2030, 1.57 billion in 2040 and 1.65 billion in

2050, we have to produce 190, 210, 225 and 240 million tonnes of vegetables by respective years. With increasing trends in processing and export, the production targets are likely to further increase. Under such a scenario production target of 375 million tonnes quality vegetables from 15 million ha with productivity of 25 t/ha coupled with reduction in post-harvest losses to 10% by 2050 appears an achievable proposition.

The targeted production needs to be achieved through utilizing scientific, technological and traditional strengths in a sustainable manner without increasing substantial area under vegetables. Domestic comfort ability and global competitiveness can only be achieved by increasing productivity, reducing cost of production, vertical expansion in area and developing region specific and need based technologies in vegetables. The positive growth in vegetable production will lead to significant emergence of processing and export sector generating on-farm and off-farm employment opportunities in the country. This document describes strategies and way forward to achieve targeted vegetable production which is sustainable, technologically sound, economically viable and environment friendly.

❑

Challenges

- Low productivity of vegetables in India as compared to other countries.
- Regional disparity in the country in productivity of vegetables.
- Lack of multiple stress resistant/tolerant varieties and climate resilient technologies.
- Inadequate availability of planting material of improved varieties.
- Inadequate varieties and eco-friendly agro-techniques for export, processing, organic, riverbed, protected cultivation and improving total factor productivity (TFP).
- Low input use efficiency.
- Depletion and conservation of natural resources.
- Inadequate infrastructure for storage, transportation, marketing, postharvest processing, value addition and export.
- Regional disparity in technological empowerment of farming community.
- Poor quality of the produce including food safety issues like pesticide residues, microbial contamination, heavy metals, colouring agents etc.
- Emergence of new pest & diseases and new strains/races/biotypes.
- Development of resistance in pests.
- Low level of investment in R & D.

Inspite of development of numerous technologies, there is a wide gap between experimental and national average yield which needs to be minimized by strong extension interventions. Frontline demonstrations in vegetable crops with the financial support from Department of Agriculture and Cooperation, Ministry of Agriculture would be a step forward in this direction. Such demonstrations will also provide feedbacks on assessment and refinement of technologies.

With liberalization of seed policy, large quantities of seeds of vegetables are being imported and marketed in the country. This poses a threat of introducing new diseases and pests in the country. A strong quarantine of such seeds before commercial sale/distribution is required.

Global climate change is projected to cause increase in the surface air temperature by 1.8 to 4.0°C by the end of this century. This will be accompanied by increase in the frequency of climatic extremes such as heat and cold waves, erratic rainfall and thereby a likely increase in the frequency of drought and flood. All these pose immense challenges to agriculture and vegetables are no exception. Adaptive mechanisms like development of varieties, time adjustment and effective use of water will help reduce adverse impacts of climate change. Biotechnological interventions such as identification and utilization of the genes for tolerance to high temperature, flood and drought would go a long way in developing suitable varieties.

India has witnessed rapid growth in horticultural sector in recent past. However, the increased production could not keep the horticultural produce in fresh condition for longer time due to poor infrastructure for storage, processing and marketing as large quantities of fruits and vegetables perish to the extent of 5-30 %. Considerable losses of perishable vegetables occur due to lack of cold chain storage facility and suitable post-harvest handling practices during post-harvest handling and marketing. Lack of mechanized sorting facilities, inappropriate packaging and poor transport systems further add to the deterioration of perishable vegetables.

Bio-risk is increasing in agriculture with climate change, intensive cultivation, emergence of new and more virulent strains of pests, and trans-boundary migration of insect-pests and diseases. It is adding cost, reducing product quality and is adversely affecting farm income. To overcome the problem of bio-risk, efforts are needed to understand the genetic basis of pathogen variability; quick, cheaper but robust diagnostic tools; effective interception mechanisms and development of effective and integrated risk management systems including remote sensing. Bio-risk intelligent system (surveillance of racial pattern of different pathogens and pests and early warning systems) need to be developed for taking informed decisions at the local, regional and national levels.

❑

Operating Environment

Vegetable Research

- Considering the importance of vegetables, All India Coordinated Research Project on Vegetable Crops (AICRP-VC) was initiated by the Indian Council of Agricultural Research (ICAR) during 1971 at Indian Agricultural Research Institute (IARI), New Delhi to plan, coordinate and monitor the research activities on vegetable crops. In order to meet the emerging challenges and to give a fillip to the research on vegetable crops, the status of AICRP-VC was elevated to the Project Directorate of Vegetable Research (PDVR) in 1986. North eastern Indo-Gangetic plains being the major vegetable growing area, the Head Quarter of PDVR was shifted to Varanasi in 1992. In 1999, a full-fledged Indian Institute of Vegetable Research (IIVR) was established at Varanasi to further boost and strengthen systematic research on vegetable crops in the country.
- The Institute at Varanasi (with 60 ha farm area) having 44 scientists, 24 technicians, 13 administrative staff and 16 skilled supporting staff carries out its research activities through 3 divisions viz., Division of Vegetable Improvement, Division of Vegetable Production and Division of Vegetable Protection. Since its inception in 1999, the institute has developed 24 state-of-the-art modern laboratories, farm facilities, expert human resources, seed production programme and effective linkages in the fields of vegetable research, education, production and transfer of technologies. :
- The current research activities at the institute comprise of 6 mega programme viz., Integrated gene management; Seed enhancement in vegetables; Productivity enhancement through better resource management; Integrated plant health management; Post-harvest management and value addition; and Prioritization of R&D needs and impact analysis of technologies developed by IIVR; one flagship programme on Yellow Vein Mosaic Virus of okra and 15 externally funded research projects.
- AICRP-VCwas also continued under the umbrella of IIVR, Varanasi with 29 regular and 25 voluntary centres distributed in different agro-climatic regions across the country. AICRP centres are staffed with 77 scientists, 83 technicians, 1 administrative staff and 10

skilled supporting staff. This project is aimed at multi-location evaluation of improved varieties/hybrids and production/protection innovations in order to identify region specific vegetable varieties/hybrids and production/protection technologies.

- Realising the importance of quality seeds, a separate Seed Production Centre (SPC) was established at Sargatia, Kushinagar, U.P. in an area of 75 ha during 2003 with the objective of enhancement in breeder and truthful level seed production of released varieties of vegetable crops.
- Three Krishi Vigyan Kendras (KVKs) at Kushinagar (2005), Deoria (2007) and Sant Ravidas Nagar (2007) districts with a sanctioned post of 16 in each were established under the administrative control of IIVR for dissemination of modern agricultural technologies in respective districts through frontline demonstrations, on-farm trials, training, showcasing, publications, etc.

Significant Achievements of IIVR

- IIVR, being an active germplasm center for vegetables in India, facilitates multiplication, conservation and evaluation of vegetable germplasm in collaboration with NBPGR, New Delhi. IIVR holds 5320 germplasm accessions of 23 vegetables. Germplasm repositories of vegetables at IIVR are enhanced through regular introductions from international genetic resource centers, indigenous collections and vibrant pre-breeding programmes.
- Novel genetic stocks generated and identified in different vegetable crops at IIVR have been deposited and registered with NBPGR, New Delhi. The important ones are: Seedless Pointed gourd (INGR03035), Downy mildew resistant Snap melon (INGR07044), Jointless tomato mutant (INGR06036), High carotenoids pumpkin (INGR05027), High lycopene tomato (INGR06037), Leaf curl resistant chilli (INGR07039), Gynoecious bitter gourd (INGR03037), Dwarf okra (INGR05026), Thin and long fruited okra (INGR09125) and Male sterile carrot line (INGR10110).
- So far, the institute has developed 39 improved varieties and 7 hybrids in 16 vegetable crops which are suitable for growing in different agro-climatic zones of the country and many of them are resistant/tolerant to biotic stresses. Impact analysis studies conducted on IIVR developed vegetable varieties have indicated their potential to enhance productivity of respective crops in the range of 6-25 %. Kashi Pragati in okra, Kashi Kanchan in cowpea and Kashi Anmol in chilli are the most successful varieties adopted by the growers of

Eastern Uttar Pradesh with more than 20% increase in productivity. High yielding varieties developed by the institute in garden pea (Kashi Nandani, Kashi Udai and Kashi Mukti), pumpkin (Kashi Harit) and sponge gourd (Kashi Divya) exhibit an average increase of more than 10% yield at farmers' fields.

- Biotechnological approaches for gene pyramiding in tomato for resistance to tomato leaf curl virus disease (*Ty-1+Ty-2+Ty-3)*; identification of QTLs for pungency and oleoresin in chillies, tolerance to moisture stress in tomato, tolerance to fruit and shoot borer in brinjal and tomato; and allele mining for desirable attributes have begun to deliver promising products for sustainable vegetable growth.
- Integrated Plant Nutrient Management (IPNM) studies conducted at IIVR indicate likely increase in the vegetable productivity to the extent of 18-40% over the recommended practices on account of improvement in physical, chemical and biological properties of the soil. These IPNM modules can increase net-profit, quality attributes of vegetables and minimize the use of chemical fertilizers up to 15-20%.
- Development of improved agronomic practices can enhance nutrient use efficiency, restore soil fertility and sustain productivity. Different agronomic practices developed at this institute can enhance nitrogen use efficiency from 0.099 t/kg N to 0.229 t/kg N in different vegetable crops.
- Due to demand of water in domestic and industrial use, there is increasing pressure for judicious use of water for agricultural purpose. Considering its scarcity, various options such as drip fertigation, mulching, regulated deficit irrigation, furrow irrigated raised bed planting etc were standardized to improve water productivity in tomato and okra. In tomato, drip irrigation at 100% pan evaporation (PE) and black polythene mulching saved 46% water whereas furrow irrigated raised bed planting and paddy straw mulching resulted into water saving of 49%. With cyclic alternate furrow irrigation in tomato, water use efficiency of 1.10 t/ha/cm and water saving of 27% could be obtained. In okra, drip irrigation at 100% or 80 % ET0 could save water to the tune of 31-47%.
- In case of tomato, drip irrigation at 100% pan evaporation (PE) and black polythene mulching results water use efficiency 3.50 t/ha/cm and saves 46% irrigation water, furrow irrigated raised bed planting and paddy straw mulching results water use efficiency of 1.43 t/ha/cm and saves 49% irrigation water, Cyclic alternate furrow

irrigation results water use efficiency 1.10 t/ha/cm and saves 27% irrigation water. In case of okra drip irrigation at 100% or 80 % ET0 (reference evapotranspiration) results water use efficiency 2.75-4.21 t/ha/cm and saves 31-47% irrigation water. Surface irrigation at 10 days interval and dry grass mulching @ 7.5 tones/ha results water use efficiency 3.51 t/ha/cm and saves 45% irrigation water. In case of broccoli, drip irrigation at alternate day with 100% PE results water use efficiency 1.14 t/ha/cm and saves 56% irrigation water.

- Organic farming, especially of vegetables is gaining momentum worldwide due to increasing awareness and concern on adverse effects of indiscriminate use of chemical fertilizers and pesticides on food quality, soil health, human health and environment. The studies conducted at IIVR on tomato, cabbage, cowpea and okra revealed that application of poultry manure @ 7.5 t/ha can ensure 28-35 % higher yield as well as 17-25% higher vitamin-C content in these crops over the inorganic management system and the soil health in terms of organic carbon, bulk density, water-holding capacity, microbial biomass carbon and dehydrogenase activity was improved under organic system as compared to inorganic system.
- Zero tillage on permanent ridges with residue retention can save inputs cost to the extent of ₹18,394/ha/yr and energy saving to the tune of 9626 MJ/ha/yr. As much as 61 L/ha/yr of fuel could also be saved by zero tillage practices. In cowpea-tomato cropping sequence with zero tillage, the net economic benefit of ₹ 1,58,265/ha/yr could be realized as against ₹ 1,05,484/ha/yr under conventional tillage. Organic carbon storage, labile organic carbon content, carbon pool index and carbon management index were higher by 4.67 Mg/ha, 0.06 g/kg, 0.34 and 17.5, respectively under zero tillage with residue retention.
- High post-harvest losses and surplus during glut season demand preservation of vegetables using low cost technologies. Among different processing techniques, drying is one of the most versatile methods to preserve vegetables. Therefore, processes for drying different vegetables have been developed at IIVR to retain nutrients, colour and good sensory qualities for several months. Drying of vegetables at 50-60^{o}C for 6-8 hours retain 30-35% ascorbic acid, 90-92% chlorophyll, 60-65% capsaicin in green chilli powder and overall good acceptability score of 7.5-8.0 on 9-point Hedonic scale.
- IPM module for brinjal shoot & fruit borer developed at IIVR has a potential to reduce infestation of borer by more than 85% and

increase in yield by 40%. The total cost of production would be reduced by 30% due to reduced cost of pesticide application by 35.20%.

- IPM module for cucurbits fruit fly developed by the institute employing Male Annihilation Technique (MAT) and Bait Application Technique (BAT) was observed to reduce the fruit damage by 71% and ensure reduced pesticide applications.
- Use of effective cultural practices, biological agents and botanicals are expected to reduce pesticide use. The cultural practices, bio-control agents and botanicals identified and tested at IIVR are playing significant roles in managing wide range of pests and are important components of various IPM programme. The promising bio-control agents for various insects identified at IIVR are *Pediobious foveolatus* against hadda beetle, *Agathis* sp and *Chelonus blackburni* against okra borer, *Actenomycetes*, *Amblyseius* sp and *Orius* sp against chilli yellow mites, and *Aenasius bombawalei* against okra mealy bug.
- Creating awareness among the farming community, trainings and outreach programmes are regular activities of the institute. In order to popularize varieties/technologies of various vegetables in the country, different mass-media approaches and massive front-line demonstrations were conducted at the farmer's fields using the recommended varieties/hybrids along with training programme. The institute has completed 52 episodes of "Vegetable School on Air" in collaboration with All India Radio, Varanasi during 2013-14. These efforts not only help farmers in solving their problems in vegetable cultivation but also help to improve their livelihood.

Other Operating Environment

- In 21stcentury, India is being recognized as the global power in the key economic sectors with consistent high economic growth but on the other hand slow growth in the agriculture sector increases concerns for the food and nutritional security. Indian agriculture contributes 8% to global agricultural gross domestic product supporting 18% of world population with only 9% of world's arable land, 2.3% of geographical area and 4% water. Approximately one-third of the country's population lives below poverty line, and about 80% of our land mass is highly vulnerable to different natural calamities like drought, floods and cyclones. However, rich biodiversity available in India (nearly 8% of the world's documented animal and plant species) offer a great opportunity for food and nutritional security. Therefore, conservation of natural resources, maintenance of biological wealth and acceleration of agricultural growth are of paramount importance in the present context as well as of the future.

- Indian agriculture is dominated by small and marginal farmers, having small land holdings. The average size of the operational land holding declined from 2.30 ha in 1970-71 to 1.16 ha in 2010-11, and absolute number of operational holdings increased from about 70 million to 138 million. If this trend continues, the average size of holding in India would be merely 0.68 ha in 2020, and would be further reduced to 0.32 ha in 2030. Declining size of landholdings without any alternative income augmenting opportunities is resulting in fall in farm income, causing agrarian distress. A large number of smallholders have to move to postharvest and non-farm activities to augment their income. The research focus should be to evolve technologies and management options to suit to the needs of small and marginal farmers.
- In addition, the quality of production environment is worsening. The problem of land and water degradations is the key constraints in augmenting agricultural production. As per the estimates available, nearly 120.72 million ha of land is degraded due to soil erosion and about 8.4 million ha due to soil salinity and water-logging in the country. Besides, huge quantities of nutrients are lost during crop production cycle (0.8 million tonnes of N, 1.8 million tonnes of P and 26.3 million tonnes of K) resulting into poor soil health and quality. Problems are further aggravated by imbalanced use of nutrients (especially nitrogen, phosphorus and potash) and excessive mining of micronutrients, leading to multi-micronutrient deficiencies in the soils.
- Similarly, the water-table is lowering steeply in most of the irrigated areas and water quality is also deteriorating due to leaching of salts and other pollutants. The green-revolution belt is experiencing second-generation problems owing to over-exploitation and mismanagement of natural resources. All these problems can be rectified by efficient management practices.
- There should be strategies to ensure end-to-end holistic approach towards post-harvest management, processing and marketing to assure returns to growers and also to assist retailers and whole-sellers in setting up facilities of pack house with cold chain facility, ripening chamber, modified atmospheric packaging and controlled atmospheric storage of vegetables. Edible coating of polysaccharides, lipids and proteins may be helpful in retaining the freshness of

vegetables for longer time. This will also be helpful in retaining the aesthetic quality of vegetables. Value addition of vegetables can convert the surplus vegetables into nutritionally rich processed products with wider acceptance. Minimally processed vegetables reduce the time of cooking with various health benefits. Similarly, ready-to-eat vegetables provide varied taste and convenience of time with extended shelf life.

- Agri-marketing in India is still unorganized and inefficient showing 18 to 25% losses in the entire supply-chain. However, now a days, the arena of agricultural marketing including agri-business in the supply-chain operations and management is expanding due to entrance and investment by corporate sectors. Thus, it links production sector with consumers in the promising domestic and global markets.
- Further, food diversification and globalization is opening enormous opportunities for food and processed commodities. The critical issue for the future of the Indian agriculture is to evolve mechanisms for linking front-end activities of agricultural supply-chain (wholesale, processing, logistics and retailing) with its back-end activities of farm production that would lead to enhanced efficiencies, ensured remunerative prices to producers, assured markets and reduced production and market risks. There are plenty of opportunities for strong public-private partnerships in the agricultural research and development as well as for fostering relevant agro-enterprises and technology incubators.
- Increase in smallholdings, rising food demand, increasing uncertainties, unfolding globalization and emerging private sector in agri-research and agri-business call for designing policies, developing institutional mechanisms, evolving decision-making processes, mobilizing political support and improving governance of service providers.
- Emergence of the intellectual property rights regime is the added challenge, which needs to be converted into an opportunity. All these issues require effective and need-based institutions to accelerate innovations and link farmers with different stakeholders to harness growing opportunities. Innovative institutional models, pro-agricultural policies and regulatory mechanisms would be evolved for accelerating innovations, ensuring food security, enhancing livelihood opportunities of small and marginal farmers and also for conserving natural resources.
- The research programs at IIVR will need continuous refinement to

enhance the quality of vegetable research and to solve the immediate and future problems of vegetable production. This will require the development of human resources through training of scientists at the centres of excellence. Although, the institute's mandate does not reflect direct involvement in teaching, however, the scientific faculty of the Institute is guiding M.Sc. & Ph.D. students from agriculture as well as other universities. Linkages with reputed national and international organisations such as CGIAR institutes and other knowledge centres need to be strengthened to give exposure and upgrade the knowledge of scientists/faculty of the institute.

- Besides, development of new vegetable technologies to enhance production and productivity, effective dissemination of these technologies to appropriate stake holders is equally important. The institute organizes various trainings for vegetable growers in different locations of the country and also organizes seminars, symposium, workshop, etc. for dissemination of recent advances in vegetable technology. Moreover, there is a need to exploit modern tools of communication like mobile phones and internet services for effective technology transfer. Similarly, linkage with ATMAs, KVKs, and SAUs etc. will be the focus for exchange of knowledge and technology for ultimate beneficiaries.

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Opportunities

- The strength of vegetable research and development in our country is the rich biodiversity, potential market, higher involvement of family work force and qualified scientific manpower.
- In our country varied climatic conditions offer best scope to select the suitable niches according to nature of crop. The existing agro-climatic conditions can be capitalized for vegetable production.
- Biotechnological interventions like marker assisted selection, allele mining, marker-free genetic transformation with genes of plant origin, genome sequencing, functional genomics, proteomics and phenomics have several opportunities to address unsolved problems of varietal development. Genome sequencing of important indigenous vegetables, especially okra, bitter gourd, brinjal, Dolichos bean, pointed gourd, ash gourd, Coccinia spp., indigenous melons, Luffa, drumstick, curry leaf, amaranth etc. will provide several opportunities to identify economically important genes in our own bioresources.
- Business opportunities in the area of quality seed & planting material production, storage and processing would increase steeply for vegetable crops. Several private entrepreneurs have already captured this opportunity and are increasing their capacity for quality seed production.
- Similarly, prospects in the area of postharvest processing would increase many folds in near future. There is a need to refine the storage technology to economize energy consumption as well as to ensure better quality of stored produce.
- Tremendous opportunities will also be opened in the areas of contract farming, crop insurance, consultancy, mechanization, hi-tech farming, organic farming, family farming, procurement, packaging, retailing etc.
- Industrial use of vegetables for colour, cosmetics and aesthetic value etc.
- Vegetables are rich source of vitamins, minerals, glucosinolates, anti-oxidants etc. There is great potential for their use as functional and health foods.
- Employment generation with greater focus on women work force.
- Crop diversification in cropping system.

- Agricultural research in future will be benefitted by latest developments in areas like nano-technology; information and communication technology; remote sensing; geographic information system (GIS); and global positioning system (GPS). These frontier sciences and techniques would be well integrated in the on-going and future agricultural research for improving research efficiency and output.

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Goals and Targets

The achievable goals and targets by 2050 are:

- Production of 375 mt quality vegetables from 15 mha with productivity of 25 t/ha. Major enhancement is expected due to increased cropping intensity of vegetables to around 300%.
- Ensuring uniform growth of vegetables across the country by developing region-specific production technologies.
- Ensuring recommended *per capita* availability of vegetables (300 g) to usher nutritional security in the country.
- Developing vegetable production technologies that are technologically sound, resource sustainable, economically viable, socially acceptable and environment friendly.

IIVR will also strive to (i) evolve technologies helpful in reducing post-harvest losses to 15% from current 25%, (ii) enhance value addition and processing to 15% of total vegetable production and (iii) enhance export of fresh vegetables and vegetable products to 10% of total vegetable production. However, these attempts need policy and developmental backing from the government.

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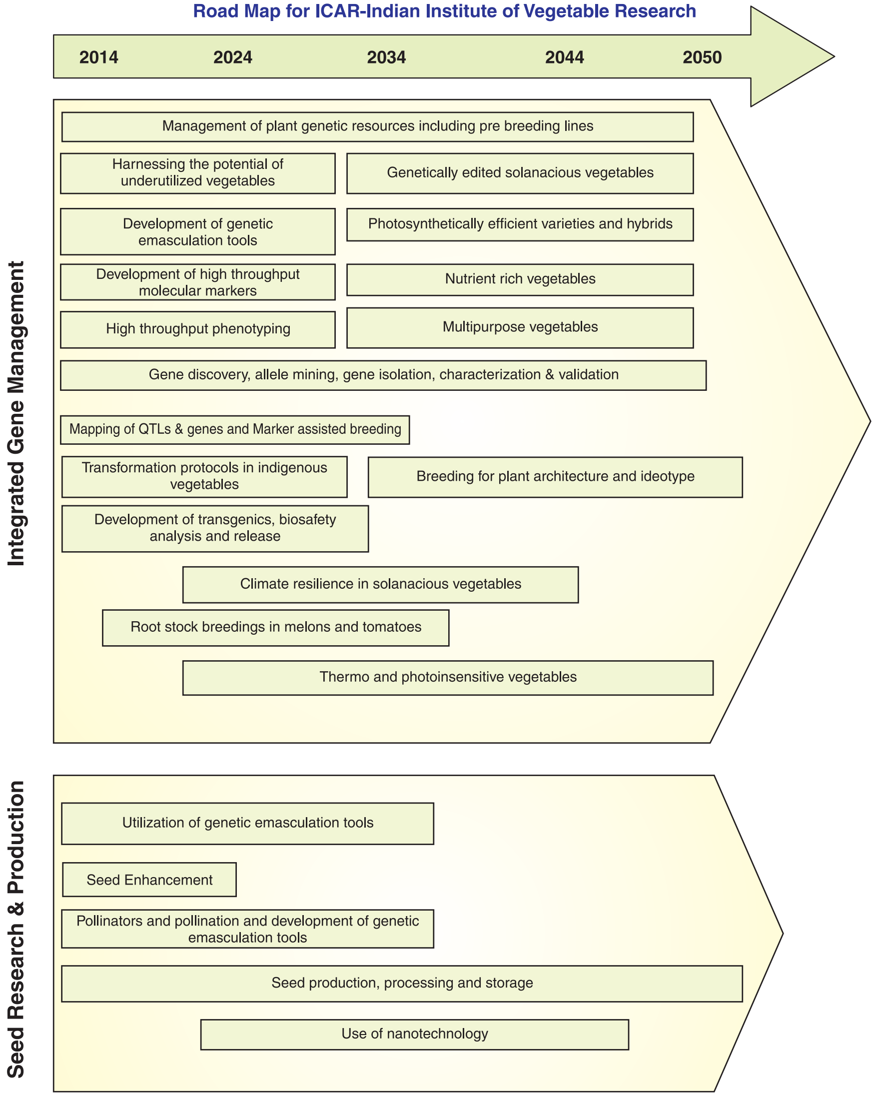
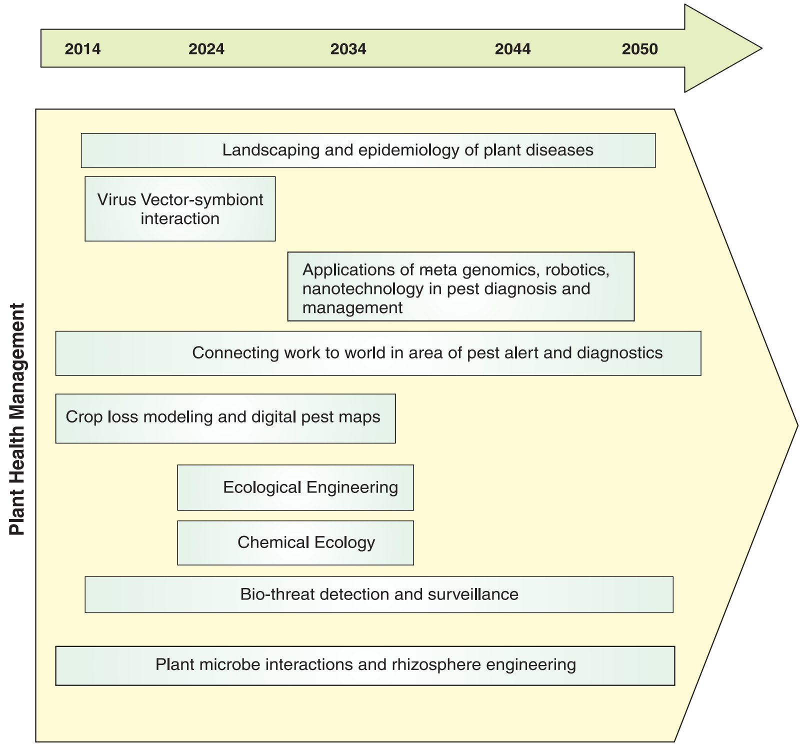
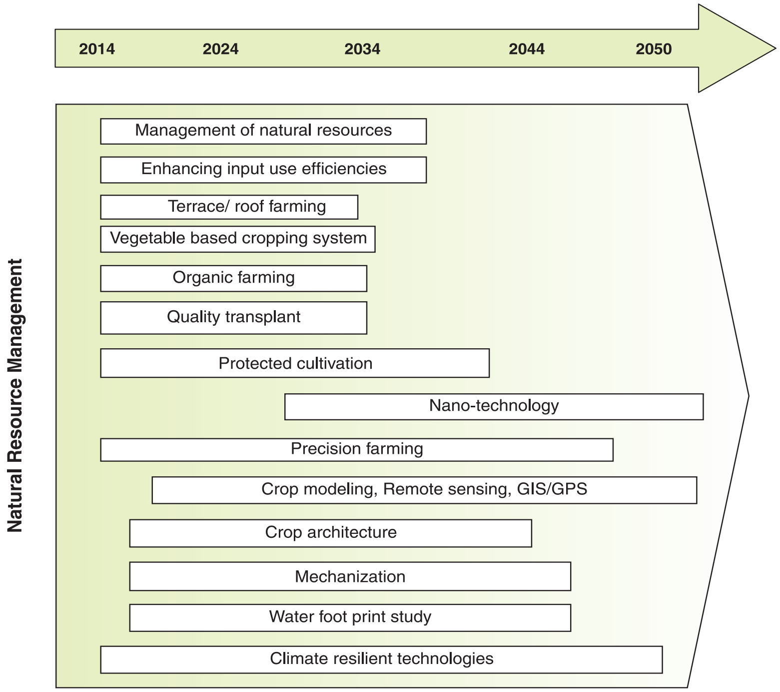
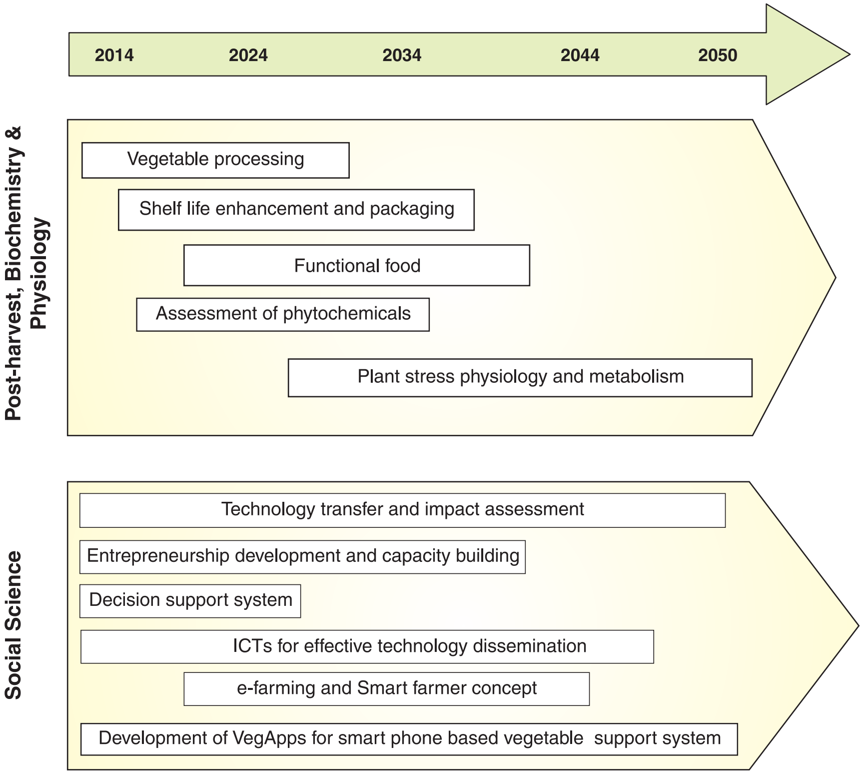
Road Map for ICAR-Indian Institute of Vegetable Research




2014
2024
2034
2044
2050
Plant Health Management
Landscaping and epidemiology of plant diseases
Virus Vector-symbiont interaction
Applications of meta genomics, robotics, nanotechnology in pest diagnosis and management
Connecting work to world in area of pest alert and diagnostics
Crop loss modeling and digital pest maps
Ecological Engineering
Chemical Ecology
Bio-threat detection and surveillance
Plant microbe interactions and rhizosphere engineering


2014
2024
2034
2044
2050
Natural Resource Management
Management of natural resources
Enhancing input use efficiencies
Terrace/ roof farming
Vegetable based cropping system
Organic farming
Quality transplant
Protected cultivation
Nano-technology
Precision farming
Crop modeling, Remote sensing, GIS/GPS
Crop architecture
Mechanization
Water foot print study
Climate resilient technologies


2014
2024
2034
2044
2050
Post-harvest, Biochemistry & Physiology
Vegetable processing
Shelf life enhancement and packaging
Functional food
Assessment of phytochemicals
Plant stress physiology and metabolism
Social Science
Technology transfer and impact assessment
Entrepreneurship development and capacity building
Decision support system
ICTs for effective technology dissemination
e-farming and Smart farmer concept
Development of VegApps for smart phone based vegetable support system

Way Forward

Integrated Gene Management

Genetically edited vegetables: Genetic editing involves tweaking or altering already existing DNA sequence to increase or decrease quantity of naturally existing bio molecules of a vegetable. There by the technique avoids the insertion of foreign genes, and associated concerns and apprehensions that are associated with GM crops. The 'Genetically Edited Vegetables (GEV)' with higher amounts of bioactive components may play better role in preventing/fighting chronic non communicable diseases in addition to providing basic nutrition. Development of vegetable cultivars that possess higher proportion of bioactive phytochemicals, tolerance to biotic and abiotic stresses through the use of new biotechnology techniques like "Genetic Editing" is envisioned for 2050.

Climate-proof vegetables: With tolerance to drought, heat, heavy metals, cold, Ozone and other aerosols: With ever increasing urbanization, urban and peri-urban vegetable production has higher role to play to meet the vegetable requirement of urban population. This brings us to a situation where more vegetables might have to be produced in an environment that may have higher levels of heavy metals, ozone, aerosols and other pollutants linked to urbanization and degradation of natural resources. Therefore, development of vegetable varieties that can grow in such environments and that can prevent entry of heavy metals, other pollutants into food chain is envisaged.

Root stock breeding and molecular genetics of root stock and scion interaction: Grafting is a promising tool to improve the tolerance of fruit vegetables against abiotic stresses like salinity, cold, heat, drought, flooding and nutrient deficiencies. Therefore breeding of suitable rootstocks resistant and tolerant to different biotic and abiotic stresses is a promising option in solanaceous and cucurbitaceous vegetables. The strategy is to focus on selection of rootstocks that further increase yield potential of scions under diverse growing conditions. The modern breeding tools would beintegrated to understand the genetic basis of root stock and scion interaction in vegetables. Understanding the molecular mechanisms that probably underline the graft-induced changes could pave the way to a better knowledge over the rootstock-scion interactions, the role of rootstock in scion performance and eventually the improved quality and fruit harvest from grafted vegetable plants.

Photosynthesis efficient varieties and hybrids: Improved photosynthetic efficiency in crop plant is generally regulated by a network of genes and can be identified using modern genetic techniques. Genetic improvement of crop photosynthesis could be achieved through indirect means. Selection for a high and sustained stomatal conductance and manipulation of assimilate allocation to the reproductive primordia to establish a large potential sink could indirectly increase total crop photosynthesis. Manipulation of key photosynthetic enzymes for increasing photosynthesis, manipulation of catalase to reduce photorespiration and modification of chloroplast genome through modern biotechnological tools may also pave the way for development of photosynthesis efficient genotypes in vegetables.

Thermo and photo insensitive vegetables: Many vegetables are photo and thermo sensitive in nature and need a definite photo period and temperature for growth, development, flowering and fruiting. This makes them seasonal and localized. Development of photo and thermo insensitive varieties may break the area and seasonal boundary for the cultivation of several vegetables. Isolation of photo insensitive genotypes in vegetable will also help to grow short day vegetables under long day condition and vice versa. Development of high temperature tolerant strains in temperate vegetables can enable their cultivation in intermediate as well as subtropical areas. Conversely cold tolerance in tropical vegetables will be beneficial in evolving genotypes for temperate areas.

Metabolomes profiling and development of nutrient-rich vegetables: A better understanding of the pathways responsible for the biosynthesis of nutritionally relevant metabolites in vegetables is a key to breed nutrition rich vegetables. Generation of metabolome profile of vegetables with an emphasis on indigenous vegetables would a foundation for achieving enhanced nutrient levels in vegetables. The metabolomics approaches would be employed to decipher ultimate biochemical outcome of changes in the genome, transcriptome and proteome that could be exploited for enhancing the metabolic value of new vegetable varieties.

Multi-purpose vegetables including vegetables for biofuel: Vegetables are one of the main sources of nutrients in human diet. Nutrients are obtained from different parts of vegetable crops such as leaves, fruits, roots and even stems etc. Development of multipurpose vegetable crops will be required to fulfil the increasing demand of vegetables. The same plant producing fruits as well as leafy vegetable will give the multiple yield and income to farmers. Similarly crops with high biomass can be designed to produce biofuel as a by-product. Vegetables crops with high biomass are suitable for this. The metabolic engineering using genes for synthesis of biofuel in model plants is a successful example and the same strategy can be further extended to specific vegetable crops to develop multiproduct crops. Such multiproduct crops will produce vegetables and clean and cheap energy from dry biomass.

Breeding for plant architecture and ideotype: Plant ideotype modelling is the concept in which given plant type is expected to perform or behave in a predictable manner within a defined environment. Plants with model characteristics known to influence photosynthesis, growth and yield with minimum demand on resources per unit of dry matter produced. The modern breeding strategies should focus on those physiological traits with increased photosynthetic activity, more adaptation to biotic and abiotic stress, minimum energy spend on inputs with maximum dry matter production. Opportunities will be explored to alter the crop duration, timing of crop development, primary growth of plant (form), canopy architecture, branching, shoot and root growth etc. which may help to escape the Insect pest attack or abiotic stress

Genetically engineered vegetables for edible vaccines: Edible vaccines are the important alternatives for traditional vaccines to reduce the burden of diseases like hepatitis and diarrhoea particularly in developing world where storing and administering vaccines are the major problems. Vegetables could be used as the potential target for developing edible vaccines and antibiotics as they are cheap and yield high. Similarly vegetables can be engineered for proteins with high content of essential amino acids, antioxidants, minerals and enhancing the shelf life of vegetables.

Additionally, following strategies are envisaged under integrated gene management;

- Germplasm explorations for collecting natural variability in common and underutilized vegetables based on gap analyses (crop-, trait- and area-wise analyses of available germplasm).
- Multilocation evaluation, cataloguing of germplasm and development of core sets in vegetables using both trait based evaluation and molecular marker methods.
- New generation pre-breeding for genetic enhancement of tomato, brinjal, chilli, cucumber, gherkin, melons, pumpkin, bitter gourd, Luffa, cabbage, cauliflower, carrot and okra using genomic resources.
- Anticipatory trait breeding for new and emerging diseases and insects of vegetables.

- Genomics aided breeding and creation of genomic resources for indigenous vegetables such as bitter gourd, okra, pointed gourd and brinjal.
- Development and deployment of genetic emasculation tools such as male sterility, self-incompatibility and gynoecium in important vegetable crops.
- Resource use efficient varieties and hybrids for efficient use of water, fertilizer, radiation and energy
- Developing parthenocarpy in cucumber & gherkin, pointed gourd, tomato and other vegetables.
- Double haploid and reverse breeding for rapid genetic enhancement of selected vegetable crops.
- Evolving varieties/parental lines in mandate crops having short duration, high yield, multiple abiotic/biotic stresses resistance, processing qualities, export qualities and high nutrient content.
- Breeding for special and/or challenging production environment such as rainfed/tropical areas, protected cultivation, riverbed cultivation and organic production.
- Biotechnological methods such as development of markers for marker assisted selection (MAS), gene pyramiding, gene/allele mining and transgenics would be employed to achieve accuracy and efficiency in genetic enhancement programs.
- Designing new plant architecture in commonly grown vegetables to increase productivity and promoting new crop types by harnessing the potential of under-utilized vegetable crops.

Seed Research and Production

Seed Production Hubs and Seed Export Zones for vegetables: Indian vegetable seed industry is growing immensely. Using the diverse agro-climatic conditions and availability of inexpensive farm labour including women, India can create vegetable seed production hubs for production of open pollinated varieties and hybrids in several vegetables. This will help to cut down the import of vegetable seed and simultaneously create the export potential. Also, this will have a positive influence on Indian economy in terms of employment generation and earning foreign exchange. Through skill development and participatory seeds production, it would be possible to improve the livelihood security of the vegetable farmers.

Seed dormancy: In some crops like Pea and beans, seeds germinate even before harvesting if there are rains at the time of maturity. A period of dormancy in such cases would check the loss due to germination.

In some vegetable, longevity of seed is very poor and lose viability very quickly. Manipulation using genetical, biochemical and mechanical approaches may alter the seed longevity.

Following strategies in seed research will also be pursued to achieve the target set for 2050;

- Use of genetic emasculation systems for economic hybrid seed production.
- Enhanced conversion rate of ovules to seed.
- Research on pollinators and pollination for efficient seed production.
- Use of nanotechnology for improving germination and vigour of vegetable seeds.
- Studies on seed physiology, biochemistry, priming, pelleting, coating and storage including modified atmosphere packing.
- Research on different agronomic aspects including disease free vegetable seed production.
- Seed production using special production environments such as protected and organic environment.
- Standardization of seed vigour tests, quick determination of seed germinability, seed invigoration, seed processing and ultra-drying.
- Mechanization in vegetable seed production.
- Biotechnological interventions for testing purity of hybrid seed.
- Development of crop based technical groups.
- Development of seed management information system.
- Production of vegetable breeder seeds and planting material as per national seed chain.

Integrated Plant Health Management

Landscape epidemiology of plant diseases: The agricultural landscapes are characterized by a high degree of heterogeneity and fragmentation. Landscape ecology focuses on the influence of habitat heterogeneity in space and time on ecological processes. The main aim of landscape epidemiology is to apply concepts and approaches originating from landscape ecology to the study of pathogen dynamics at the landscape scale. These include the influence of landscape composition on the global inoculum pressure; landscape heterogeneity on pathogen dynamics; landscape structure on pathogen dispersal and landscape properties on the emergence of pathogens and on their evolution.

Virus-Vector-symbiont interaction: Insects are major determinant in reducing the vegetable production and productivity as direct pest and vectoring of many plant viruses. The relationship of virus and insect vectors are specific to the group of plant viruses. This specificity is due to association of extremely large variety of microscopic life forms, including viruses, bacteria, fungi, protozoa and multicellular parasites in their body. This relationship of virus-vector can be managed by disruption of essential symbionts of insects, along with the manipulation of microbes involved in essential insect activities, such as vectoring ability, metabolic requirements or the resistance to natural enemies is more useful in management of insect vectors and indirectly by viruses.

Applications of meta-genomics, robotics, nanotechnology in pest diagnosis and management: The metagenomics allows the identification, characterization and exploitation of genetic material from microbial communities. It will bring out useful information on microbial interactions and that can be utilized to improve health of plants and food security. Similarly, the nanotechnology holds significant promise in management of insects and pathogens, by controlled and targeted delivery of agrochemicals and also by providing diagnostic tools for early detection. Nanoparticles are highly stable and are biodegradable; it can be successfully employed in production of nanocapsules for delivery of pesticides and other agrochemicals.

Connecting work to world in area of pest alert and diagnostics: Introduction of exotic pests and diseases is inevitable in liberal worldwide trade and travel. Advancement in science especially in the field of early detection and diagnostic is upgraded through novel technologies day by day. Connecting people of work group becomes easy through advancement in information technology. Hence a holistic approach on a global and collaborative scale is possible by bridging advancement in science (detection and diagnostics) and information technology (rapid alert techniques) to check the enemies at a time and place.

Crop loss modelling and digital pest maps: Data on economic threshold level for different pests are available however; a clear cut map on pest distribution across the regions/nation with digital identity is not available. Similarly forecasting models are available only for few or key pest that too the model(s) coupled with crop loss assessment is rare. Hence for sustainable vegetable production, an exclusive data base on digital pest maps and biosensor or remote sensing base technologies for forecasting of pest/crop loss should be developed for different pests.

Ecological Engineering: Ecological engineering has recently emerged as a new paradigm for considering pest management approaches that are based on cultural practices informed by ecological knowledge, rather than on high technology approaches such as synthetic pesticides and genetically engineered crops. Ecological engineering is a human activity that modifies the environment according to ecological principles.

It is the habitat manipulation that aims to provide the natural enemies of pests with resources such as nectar, pollen, physical refugia, alternative prey and alternative hosts.

Chemical Ecology: Chemical ecology is the study of the structure, origin and function of the naturally-occurring chemicals that mediate interactions between individuals of the same species and/or interactions between individuals of different. The field of chemical ecology in pest management was first explored in the first identification of an insect sex pheromone and since then our knowledge on the role chemical mediated cues between and within the species has significantly increased. Different semiochemicals mediated interactions, role of allelochemicals, pheromones and others compounds in different group of insects and other arthropods need to be studied for exploitation in pest management.

Bio-threat detection and surveillance: Rapid advancement in international trade and tourism is one way leading to introduction of exotic and invasive pests from one part to other part of the world. Biological threats are most dangerous problems at the international level, which can lead to loss of lives, affects the sustainability of agricultural production and food security. This has to be addressed through stringent regulations, policies, adequate human resource development and development of rapid, sensitive, low cost and easy to use detection devices such as mobile infrared spectroscopy, and high-density protein microarrays and next-generation immunoassays.

Plant microbe interactions and rhizosphere engineering: Plants live in intimate contact with microorganisms some of which cause disease and while others protect the plant against disease. Extensive investigations are necessary to know the microbial diversity, type of interactions and to rapidly identify microbes for utilizing useful ones or their products for managing the disease and sustainable agricultural production. Development of sensitive *in-situ* diagnostic devices for root exudates and most common beneficial microbes is required to modulate plant microenvironment to get better yield.

Following additional strategies in plant health research will also be pursued to achieve the target set for 2050

- Development of precise pest forecasting system and precision diagnostics kits for pathogens.
- Identification of genetic resistance sources for pests.
- Biotechnological interventions for identification of race/strain/biotype of pests.
- Improving the efficacy and delivery of biocontrol agents, biopesticides and novel chemical pesticides.

- Integrated management of important insect & nematode pests, fungal, bacterial and viral diseases with changing climate scenario under open and protected conditions.
- Bioprospecting of beneficial microbes for pest management and plant growth promotion.
- Dynamics of emerging pests/biotypes/races/strains etc. in relation to changing climate.
- Characterization and identification of novel and pure compounds from botanicals.
- Info-chemicals involved in tritrophic interaction (Host-Pest-Natural enemies) for use in pest management.
- Conservational biological control.
- Pesticide resistance management strategies for important pests.
- Monitoring of pesticide residues and their management.

Productivity Enhancement through Better Resource Management

Enhancing carbon sequestration/carbon capture through conservation practices in vegetable farming: Soil organic carbon (SOC) is vital forimproving soil quality and sustaining the productivity of agro-ecosystems and in mitigating greenhouse gas (GHG) emissions, the principal cause of global warming. Inter-governmental panel on climate change (IPCC) has recognized carbon sequestration in soils as one of the main options for GHG mitigation.Quantification of SOC in relation to various crop management practices is of importance in identifying a sustainable system for C sequestration in soils and increasing crop productivity under sub-tropical environments. The appropriate management technologies and suitable vegetable production systems will be developed for a positive impact on carbon sequestration and soil quality. This would help us in achieving the goal of food security, as well as, in improving soil carbon sequestration for mitigation of climate change.

Energy, water, nutrient efficient and off season vegetable production technology: The efficient utilization and management of resources and increasing input use efficiency in vegetable crops are of utmost important to future farming. High tech interventions involving precision farming micro-irrigation, fertigation, protected/ greenhouse cultivation, mechanization, soil and leaf based fertilizer management and use of modern tools like geo-informatics (Remote sensing, GPS & GIS). Water foot print of vegetable production, crop modelling and decision support systems will facilitate the development of appropriate technologies for improving crop productivity and quality while minimizing the cost of inputs. Besides, with the recent advances in sensor technology, it would be possible to promote smart vegetable farming using the state of the art sensor based automated delivery of inputs like water and nutrients.

Vegetable based cropping systems: Development of efficient vegetable based crop rotations/cropping systems to harness synergistic/ positive interactions of companion crops/crops in sequence and to minimize negative allelopathic effects is of paramount significance in achieving the objectives of enhancing productivity, input use efficiency and sustaining environmental quality. This would also help in minimizing the infestations of weeds and recurrence of pests and diseases.

Organic farming for safe nutrition and environment: Contamination of vegetables, fruits and other food commodities with harmful pesticide residues and pollution of the environment due to indiscriminate use of inorganic fertilizers and pesticides is a matter of concern all over the world. Development of suitable organic farming modules in vegetable crops would help in production of safe vegetables, minimizing environmental pollution and improving soil health through enhanced carbon sequestration and biological activity.

Nano-technology for enhancing fertilizer use efficiency and smart delivery of nutrients: Low fertilizer use efficiency of 20-50 percent for nitrogen and 10-25 percent for phosphorus (<1% for rock phosphate in alkaline calcareous soils) of applied nutrients in soil is of prime concern as it leads to wastage, as well as, movement into the groundwater posing environmental problems. Nanotechnology can be exploited to revolutionize vegetable production through development of efficient and cheaper fertilizers, enhancing the ability of plants to absorb nutrients, more moisture retention by encouraging microbial polysaccharide production, and can improve our understanding of the biology of different crops. Development of slow release nano-fertilizers formulations can be used for smart release of nutrients that commensurate with crop requirements and thereby reduce nutrient losses and improve nutrient use efficiency of vegetable crops.

Integrated use of crop growth models and geo-informatics for climate change studies and development of climate change mitigation strategies: Crop growth simulation models are powerful tools for evaluating crop responses to environment and suggesting crop management alternatives over a wide range of environments find a place in assessment of the impacts of climate change on crop yields. The availability of effective simulation models for vegetables crops is lacking. Development/validation of crop growth models are necessary and they have the potential to be used for assessing the impact of climate change, evaluate mitigation strategies and also in yield forecasting in vegetable crops on a regional scale after integration with geo-informatics tools like remote sensing and GIS. Besides, there is a need to study the crop-soil-weather interactions in vegetable crops which would help in generation of useful relationships that would find a place in the development of crop growth simulation models. Quantifying of greenhouse gases emissions from vegetable production systems and evaluating effect of greenhouse gases including tropospheric ozone and aerosols on the growth and development of vegetable crops are important areas that need focused attention. Such studies coupled with development of appropriate conservation technologies that help in sequestering atmospheric CO_2 in soil could aid in clean development mechanism and to earn carbon credits in the global carbon market.

Remote sensing for assessment of crop stress: Remote sensing helps in detecting these changes in reflectance from the crop canopy brought about by various crop stress like water, nutrient and insects and diseases and therefore has the potential to detect abiotic and biotic stresses in agricultural crops including vegetables. Remote sensing provides a means for rapid observation and digital recording of hundreds of plant samples within a short time. Coupled with GIS and global positioning systems (GPS), it would aid site specific crop management determination of fruit yield, quantification and scheduling of precise and proper fertilizer, irrigation needs, application of pesticides for pest and disease management and has potential for increasing net returns and optimizing resource.

Terrace farming/roof farming: With the pressure building on farmlands and its increasing cost in the urban areas, terrace gardening is only ideal alternative to grow vegetables domestically with the additional benefits of reducing global warming. The emphasis would be given on identification/development of suitable varieties/hybrids for pot culture, standardization of growing techniques such as growing media, type of containers, nutrient and pest management and selection of vegetables according to availability of space, water and light intensity.

Additionally, IIVR proposes to achieve the targets and goals for 2050 by pursuing research in following areas of vegetable production;

- Development of region specific efficient management practices for growing vegetables and improving soil health.
- Developing remunerative vegetable based intensive cropping systems for vertical expansion.
- Integrated water and nutrient management for improving productivity.

- Water foot print analysis of vegetable production.
- Technologies for organic production including use of bio fertilizers, growth promoting bacteria and organic amendments for vegetables.
- Technologies for protected, off season and precision vegetable production.
- Integrated weed management.
- Mechanization in vegetable production.
- *In- situ* moisture conservation, rain water harvesting and recycling through efficient irrigation practices.
- Development of low input technologies for resource poor farmers.
- Development of crop specific multi-nutrient formulations.
- Use of remote sensing and GIS tools for area and production estimation, monitoring of abiotic stresses.
- Use of plant growth regulators.
- Establishment of Technology Park for demonstration of the technologies to all stake holders.

Physiology, Biochemistry and Processing

Vegetable processing industry hubs and storage facility for enhancing the export of processing and reducing the post-harvest losses: India is the second largest producer of vegetable in the world and an increasing trend of production of vegetable is being observed during last few decades. Despite of this fact, *per capita* availability of and consumption of vegetable bellow the recommended daily allowance (300g/capita/day). One of the key reasons is huge post-harvest losses of vegetables due to perishable nature of vegetable and poor post-harvest infrastructure. At the same time huge demand for fresh and processed vegetable is being observed both domestic and international market. Setting up of post-harvest facilities both for fresh and processed vegetables can harness this opportunity. Setting up of pack house facilities with strong marketing chain can solve this problem. Similarly setting up processing industry at production catchment area can also solve this problem. Additionally both fresh and processed vegetable sector at production catchment zone generate huge employment opportunity for rural youth and women.

- Phenotyping of germplasm through advance physiological techniques (Carbon isotope discrimination chlorophyll florescence etc.)
- Assessment of nutrients (Vitamins, minerals, health related phytochemicals and fibre) and their bio-availability.
- Reducing post-harvest losses by developing suitable methods for handling, storage packaging.

- Developing vegetables processing technologies (drying, canning, freezing etc.) for extending the shelf life.
- Non-thermal processing for minimizing the quality and nutrient losses.
- Innovative vegetable packaging for extending shelf life.
- Shelf life evaluation of packaged vegetables through nano- technology.
- Vegetable waste processing and value addition.

Social Sciences

E-farming and Smart farmer concept: E-agriculture, describes an emerging field focused on the enhancement of agricultural and rural development through improved information and communication processes. Harnessing social media to build the e-Agriculture community to involve farmers into policy and strategic discussions, development of internet school for farmers, e- learning modules, , creation of Social Media Team (SMT) and e-Choupal model, digitalization of available information in order to complement existing and future agricultural communications efforts. Farmers could register themselves and directly gain knowledge and expertise under Smart Farmer Concept. They can extract information from agri networking sites, participate in events (e-Choupal), develop their own network, comment, share and contribute content.

VegAppS: The term "Apps" is a shortening of the term "application software". "Veg Apps" will be a mobile application developed by IIVR, which can be downloaded from IIVR website and run on smartphones and other mobile devices. The "Veg Apps" will have mobile web site bookmarking utilities such as crop advisory services, decision support, mobile-based instant messaging among the stakeholders, GPS based nutrient and pest-disease management and many other applications.

Other strategies envisaged to connect with the vegetable farmers include;

- Extension, training and transfer of technologies at field level and improved technologies adoption.
- Identification and prioritization of national and regional R&D needs.
- Information on technology adoption, its impact and required refinement, if any.
- Information on market intelligence and potential export markets.
- Development of vegetable based decision support system.
- SMART vegetable seed support for farmers.
- Vegetable extension services with appropriate ICT's.

- Technology commercialization, entrepreneurship development and capacity building.
- Region specific vegetable support system

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NOTES

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