

Potato varieties and impact of technologies: A boon for doubling farmers' income

Potato is the third most important food crop of the world, which is grown in more than 150 countries. The potato research and development led by ICAR-Central Potato Research Institute, Shimla has transformed this crop from temperate to sub-tropical crop in our country through technological interventions of >66 potato varieties, production, protection, post-harvest management and quality seed production technologies. Further, challenges such as climate resilient varieties, emerging insect-pest and pathogens, and quality seed availability need to be addressed.

POTATO is a new world crop and was first domesticated about 8000 years ago. Because of its food and nutritional importance, it is known as the 'Food for Future' and also termed as Hidden Treasure, and probably therefore the year 2008 was declared as the International Year of the Potato by the United Nations. Cultivated potato (*Solanum tuberosum* L. Group Tuberosum) originated from the Andes mountain regions of Peru and Bolivia in South America, more specifically in the basin of lake Titicaca. It is believed that the Portuguese traders first brought potato in India during late 16th to early 17th century. Potato cultivation in the country remained restricted before independence due to non-availability of locally adapted varieties and technologies for growing potato under sub-tropical Indian climatic condition. ICAR-Central Potato Research Institute, Shimla was established in August 1949 at Patna and later it was shifted to Shimla, Himachal Pradesh in 1956 in order to facilitate hybridization work and better maintenance of seed health. Besides, Shimla (HQ) its regional stations are located at Kufri-Fagu (HP), Modipuram (UP), Jalandhar (Punjab), Gwalior (MP), Patna (Bihar), Shillong (Meghalaya), and Ootacamund (Tamil Nadu). The institute played a key role in popularizing potato cultivation and utilization under sub-tropical agro-ecosystem. The major research outputs of the institute are: breeding of over 66 improved varieties, seed plot technique, national potato seed production programme and scheduling zone-wise agro-techniques. The major outcome of the scheme is 32.68 fold increase in production, 9.35 fold increase in area and 3.54 fold increase in yield during last seven decades. The area, yield and production in 1949-50 (the year of establishment of ICAR-CPRI) was 0.23 million ha, 6.59 t/ha and 1.54 million tonnes, respectively. As per 3rd Advance Estimate of DAC&FW, India produced 53.03 million tonnes of potato from 2.16 million ha area with an average yield of 24.55 t/ha in 2018-19.

Potato is an economically important staple food in both developed and developing countries because of its high yield potential, high nutritive value, easy digestibility and wholesome nature. It contains high protein-calorie ratio (17 g protein:1000 kcal) and yields more edible energy, protein and dry matter per unit area and time compared to cereal crops. The glycemic index (a measure of the effects of carbohydrates on blood sugar) of boiled potato is 56 (medium) compared to 58 in white rice and 71 in white bread. Therefore, it is a misconception that potato causes obesity and is forbidden for diabetic patient.

Potato area and production

China is the top potato producing country in the world followed by India and Russian Federation. Compared to the area, production and productivity in 1949-50, the increase over this period is 9, 33 and 3.6 fold, respectively. The main potato growing regions in the country are the North Indian plains (86%) followed by Plateau (8%) and hills (6%), which are divided into eight zones.

Impact of potato technology

Agriculture, including allied activities, contributed 13.9% of the GDP at constant prices (2004-05) in 2013-14, and this sector still accounts for 54.6% of total employment in the country. Current share of potato to agricultural GDP is 2.86% out of 1.32% cultivable area. On the contrary,

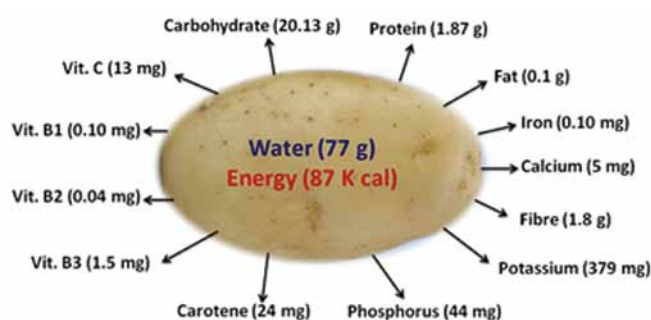


Table 1. Major potato producing countries in the world (2020)

Country	Production (million ton)	Area (million ha)	Yield (t/ha)
China	78.23	4.21	18.54
India	51.30	2.15	23.77
Ukraine	20.83	1.32	15.72
Russian Federation	19.60	1.17	16.64
USA	18.78	0.36	50.79
Germany	11.71	0.27	42.83
Bangladesh	9.60	0.46	20.82
France	8.69	0.21	40.52
Poland	7.84	0.22	34.76
Netherlands	7.02	0.16	42.67
United Kingdom	5.52	0.14	38.87
Peru	5.46	0.33	16.47
Canada	5.29	0.14	36.87
Belarus	5.23	0.25	20.64
World	359.07	16.49	21.76

(Source: FAOSTAT 2022)

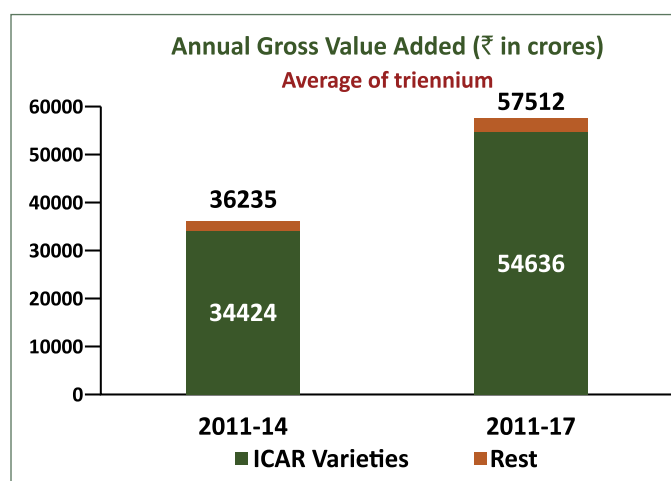
Table 2. State-wise area, production and yield of potato in India

State	Area (1000 Hectares)	Production (1000 T)	Yield (t/ha)
Uttar Pradesh	614.78	15555.53	25.30
West Bengal	427.50	12782.50	29.90
Bihar	304.78	7740.80	25.40
Gujarat	133.29	3806.95	28.56
Madhya Pradesh	136.29	3144.64	23.07
Punjab	98.52	2571.04	26.10
Haryana	34.72	897.58	25.85
Assam	102.87	720.97	7.01
Chhattisgarh	44.87	694.61	15.48
Jharkhand	48.21	690.23	14.32
Others	195.91	2705.18	13.81
Total	2141.74	51310.00	23.96

(Source: Horticulture Statistics at a Glance, 2018)

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. 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 varieties developed by ICAR-Central Potato Research Institute are very popular among farmers and cover nearly 95% of total area under potato. India produced 45.87 million tonnes of potato annually during the triennium 2014-17 and contributed ₹57,512 crore annually to the Gross Value Added (GVA) at current price. The varieties developed by ICAR-CPRI contributed ₹54,636 crore annually during this period. Four varieties,



viz. Kufri Jyoti, Kufri Bahar, Kufri Pukhraj, and Kufri Chipsona 1 together contributed around 75% of total area under potato. Potato being a labour-intensive crop requires about 145 man days for cultivation of one ha of land. Thus nearly 293 million man-days of employment have been generated only for potato cultivation during 2013-14. 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 service sectors through agricultural loans, insurance, marketing and technical consultancy, etc.

Driving factors of potato growth in country

Potato demand: 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.

Post-harvest losses: A higher proportion of potatoes (16%) is wasted as post-harvest losses than use in seed (8.5%) or processing (7.5%). 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 cause of high wastage of potatoes in the country.

Export potential: India contributes to about 13% of the total world potato production, but our contribution in world potato export is around 1.6% only, which is not even 1% of the total in-house production. Potato being semi-perishable and bulky agri-commodity, its export from India is poorly guided by a long term policy support. India being the massive producer of potatoes, a healthy growth in processed potato products is anticipated.

Potato varieties

A list of potato varieties developed by ICAR-CPRI, Shimla is tabulated here.

Table 3. Potato varieties released by ICAR-CPRI, Shimla

Variety	Year	Yield (t/ha)	Adaptability	Category/ Maturity	Important features
Kufri Kisan	1958	15-20	-	-	-
Kufri Kuber	1958	15-20	North Indian plains and plateau	Table/Early	Susceptible to late blight
Kufri Kumar	1958	15-20	North Indian hills	Table/Late	Moderately resistant to late blight
Kufri Kundan	1958	15-20	North Indian hills	Table/Medium	Moderately resistant to late blight
Kufri Red	1958	20-25	North-eastern plains	Table/Medium	Susceptible to late blight
Kufri Safed	1958	20-25	North Indian plains	Table/Late	Susceptible to late blight
Kufri Neela	1963	20-25	South Indian hills	Table/Late	Moderately resistant to late blight
Kufri Sindhuri	1967	20-25	North-Indian plains	Table/Late	Susceptible to late blight and suitable for low input area
Kufri Alankar	1968	20-25	North Indian plains	Table/Medium	Moderately resistant to late blight and early bulker
Kufri Chamatkar	1968	20-25	North Indian plains	Table/Late	Susceptible to late blight and mainly medium size tubers
Kufri Chandramukhi	1968	20-25	North Indian plains and plateau	Table/Early	Susceptible to late blight and attractive tubers with excellent flavour
Kufri Jeevan	1968	15-20	North Indian hills	Table/Late	Moderately resistant to late blight and early blight
Kufri Jyoti	1968	25-30	Hills, plains and plateau	Table/Medium	Moderately resistant to late blight, wide adaptability, early bulker, slow degeneration and day neutral
Kufri Khasigaro	1968	20-25	North-eastern hills	Table/Late	Moderately resistant to late blight and early blight
Kufri Naveen	1968	20-25	North-eastern hills	Table/Late	Moderately resistant to late blight
Kufri Neelamani	1968	20-25	-	-	-
Kufri Sheetman	1968	20-25	North-western plains	Table/Medium	Moderately resistant to late blight and frost tolerant
Kufri Muthu	1971	25-30	South Indian hills	Table/Medium	Moderately resistant to late blight
Kufri Lauvkar	1972	20-25	Plateau	Table/Early	Susceptible to late blight and heat tolerant
Kufri Dewa	1973	20-25	North Indian plains	Table/Late	Frost tolerant and good keeper
Kufri Badshah	1979	30-35	North Indian plains and plateau	Table/Medium	Resistant to late blight, early blight and PVX
Kufri Bahar	1980	30-35	North Indian plains	Table/Medium	Susceptible to late blight, moderately resistant to gemini virus and early bulker
Kufri Lalima	1982	20-25	North Indian plains	Table/Medium	Moderately resistant to late blight
Kufri Sherpa	1983	15-20	North-Bengal hills and Sikkim	Table/Medium	Resistant to late blight
Kufri Swarna	1985	30-35	South Indian hills	Table/Medium	Resistant to late blight and PCN
Kufri Megha	1989	25-30	North-eastern hills	Table/Medium	Moderately resistant to late blight
Kufri Jawahar	1996	25-30	North Indian plains and plateau	Table/Early	Moderately resistant to late blight, slow degeneration, and suitable for inter-cropping
Kufri Sutlej	1996	30-35	North Indian plains	Table/Medium	Moderately resistant to late blight
Kufri Ashoka	1996	25-30	North Indian plains	Table/Early	Susceptible to late blight
Kufri Pukhraj	1998	35-40	North Indian plains	Table/Early to medium	Moderately resistant to late blight, early bulker and requires low input
Kufri Chipsona-1	1998	30-35	North Indian plains	Processing/Medium	Resistant to late blight and suitable for chips and French fries

Table 3. (Continued)

Variety	Year	Yield (t/ha)	Adaptability	Category/ Maturity	Important features
Kufri Chipsona-2	1998	30-35	North Indian plains	Processing/Medium	Resistant to late blight, suitable for chips and French fries
Kufri Giriraj	1998	20-25	North Indian hills	Table/Medium	Moderately resistant to late blight
Kufri Anand	1999	35-40	North Indian plains	Table/Medium	Moderately resistant to late blight, tolerant to hopper burn and frost and suitable for spring season
Kufri Kanchan	1999	25-30	Nort-Bengal hills and Sikkim	Table/Medium	Moderately resistant to late blight and slow degeneration
Kufri Arun	2005	30-35	North Indian plains	Table/Medium	Moderately resistant to late blight
Kufri Pushkar	2005	30-35	North Indian plains	Table/Medium	Resistant to late blight
Kufri Shailja	2005	30-35	North Indian plains	Table/Medium	Moderately resistant to late blight
Kufri Surya	2006	25-30	North Indian plains and plateau	Processing/ Early	Susceptible to late blight, tolerant to heat and hopper burn, and suitable for early planting
Kufri Chipsona-3	2006	30-35	North Indian plains	Processing/ Medium	Resistant to late blight, suitable for chips and French fries
Kufri Himalini	2006	30-35	North Indian hills	Table/Medium	Moderately resistant to late blight, good yield in both hills and plains, and day-neutral
Kufri Himsona	2008	15-20	Indian hills	Processing/ Late	Moderately resistant to late blight and suitable for chips
Kufri Sadabahar	2008	30-35	Uttar Pradesh and adjoining area	Table/Medium	Moderately resistant to late blight and early bulker
Kufri Girdhari	2008	30-35	Indian hills	Table/Medium	Highly resistant to late blight and long tuber dormancy
Kufri Khyati	2008	25-30	North Indian plains	Table/Early	Resistant to late blight and early blight, early bulker and suitable for high cropping intensity
Kufri Frysona	2009	30-35	North Indian plains	Processing/ Medium	Resistant to late blight and suitable for French fries
Kufri Neelima	2010	25-30	Nilgiri hills	Table/Medium	Resistant to late blight and PCN
Kufri Garima	2012	30-35	Indo-Gangetic plains and plateau	Table/Medium	Resistant to late blight
Kufri Gaurav	2012	30-35		Table/Medium	Susceptible to late blight and nutrients (NPK) use efficient at sub-optimal dose
Kufri Lalit	2013	30-35	Eastern plains	Table/Medium	Resistant to late blight
Kufri Mohan	2016	35-40	Northern and eastern plains	Table/Medium	Moderately resistant to late blight
Kufri Kesar	2017	25-30	North Indian plains	Table/Medium	Moderately resistant to late blight
Kufri Sukhyati	2017	25-30	North Indian plains	Table/Medium	Moderately resistant to late blight
Kufri Lima	2018	30-35 (15-20 t/ha under early heat stress)	North Indian plains	Table/Medium to late	Susceptible to late blight, extremely resistant to PVX and PVY. Tolerant to early heat, hopper burn and mite, and suitable for early and main planting
Kufri Ganga	2018	35-40	North Indian plains	Table/Medium	Moderately resistant to late blight and tolerant to moderate drought conditions
Kufri Neelkanth	2018	35-40	North Indian plains	Table/Medium	Resistant to late blight, rich in antioxidants (anthocyanin and carotenoids), excellent flavour and speciality potatoes
Kufri Manik	2019	22-25	Eastern plains	Table/Medium	Resistant to late blight and rich in micronutrients (Fe and Zn), anthocyanin and carotenoids, and suitable for eastern plains (A bio-fortified variety)
Kufri Karan	2019	22-25	Hills and plateau	Table/Medium	Highly resistant to late blight, resistant to six potato viruses and potato cyst nematodes (PCN), and suitable for hills and plateau regions

Table 3. (Concluded)

Variety	Year	Yield (t/ha)	Adaptability	Category/ Maturity	Important features
Kufri Sahyadri	2019	30-35	Nilgiri hills	Table/Medium	Highly resistant to potato cyst nematodes, moderately resistant to late blight, and suitable for Nilgiri hills
Kufri FryoM	2019	30-35	North west and central plains	Processing/ Medium	Resistant to late blight and PVY, and suitable for french fries
Kufri Thar-1	2019	30-35	East coast plains and middle Gangetic plains	Table/Medium	Drought tolerant (under < 20% water stress)
Kufri Thar-2	2019	35	Gangetic Plains, Trans-Ganga Plains, Central Plateau and Hills and Western Dry Region	Table/Medium	Drought tolerant (under < 20% water stress)
Kufri Thar-3	2019	45	Transgangetic plains, Upper gangetic plains and Eastern plateau & hills	Table/medium	Drought tolerant, performed well in Hisar, Modipuram and Raipur locations
Kufri Sangam	2019	35-40	Gujarat plains and Hills, Central Plateau and Hills and Eastern plateau and Hills for processing; & Northern plains for table purpose	Processing & Table/ Medium	Moderately resistant to late blight and excellent storability. Suitable for both processing and Table purpose
Kufri Chipsona-4	2019	30-35	Southern plateau and hills, Lower Gangetic plains, Central plateau and hills and Gujarat plains and hillls.	Processing/ Medium	Moderately resistant to late blight This is an old institute released potato variety (in 2010) and is already in seed chain.

Prospects and challenges in potato

Tropicalization of potato to warmer regions:

Impact of global warming started manifesting potato crop and it has become imperative that further adaptation of potato from sub-tropical to more warmer growing condition would be necessary in near future to sustain its cultivation in the plains. In fact, the Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report predicted that the potato growing season in 2055 is likely to be warmer by 2.41–3.16°C. Research emphasis should be on developing short duration, early-maturing varieties with heat tolerance for both fresh consumption and processing.

Increasing crop productivity: It has been projected that India would require about 124.88 mt of potato by 2050. This enormous jump in production has to come from increasing crop productivity which is tough due to unfavourable changes in land utilization pattern and plateauing of yield gain in potato. Hence, research emphasis should be targeted on broadening genetic base of varieties, improving photosynthetic energy conversion efficiency, conferring atmospheric nitrogen fixation ability, root biology and architecture for input use efficiency and improving sink strength. Besides, emphasis should be given on diploid breeding to exploit hybrid vigour in potato and genomic tools.

Sustainable production system: During the green revolution in 1960s, all the natural resources including soil, water, energy and agricultural inputs were under severe constraint. Therefore, a paradigm shift is necessary now from the policy of mere food production to income security of farmers. Research emphasis should be given on integrated farming system approach for technology

development, water use efficiency, nutrient responsive technologies, conservation agriculture, and bio-intensive crop management. Use of information communication technology-enabled advisories, precision agriculture, drones and artificial intelligence should be encouraged for technology dissemination.

Reducing post-harvest losses and value addition:

It is estimated that ~20% of a perishable commodity like potato is lost because it is harvested at the onset of summer season. Of which about 50% losses can be prevented using appropriate post-harvest measures by establishing on-farm primary processing facilities. Hence, research focus should be given on lowering post-harvest losses by developing processing varieties and technologies, on-farm storage and primary processing units, energy-efficient storage structure, technologies for cold chipping, managing bruising injuries, value-addition and technologies for export facilitation.

Integrated pest and disease management:

Potato is affected by late blight, viruses, bacterial wilt, aphids, and other common soil and tuber borne pests and diseases. Research emphasis should be given on effective plant health management through robust diagnostic tools for effective interception of alien invasive pests and pathogens, application of pathogenomics for understanding epidemiology and management, breeding for multiple stress tolerance, use of info-chemicals for integrated pest and disease management, emphasis on biological control of pests and diseases, and decision support system and forecasting for environmental safety.

CONCLUSION

With 53.03 million tonnes potato production, India



Some of the recent potato varieties developed by ICAR-CPRI, Shimla

(2019) is the second largest potato producer after China (99 million tonnes in 2017, FAOSTAT). The target of producing 125 million tonnes potatoes in India by 2050 needs to be addressed with planned potato research and development solutions during next three decades. Currently potato is being consumed mainly as a vegetable by the entire population (~1.30 billion) of India. It is projected to increase to ~1.62 billion during 2050, out of which more than 840 million would be living in cities (against the current 375 million). Besides, much higher proportion of working women and nuclear families would 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 ICAR-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 ICAR-CPRI is enough for not only further accelerate 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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