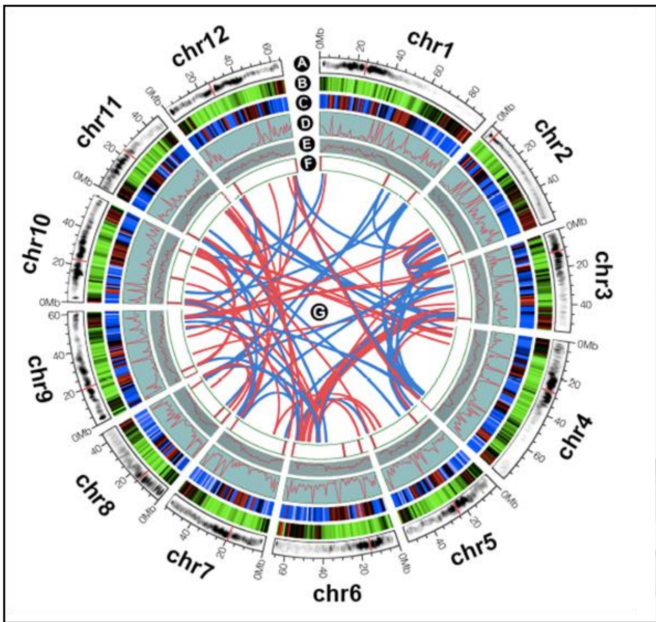
Significant outputs and outcomes during last five years

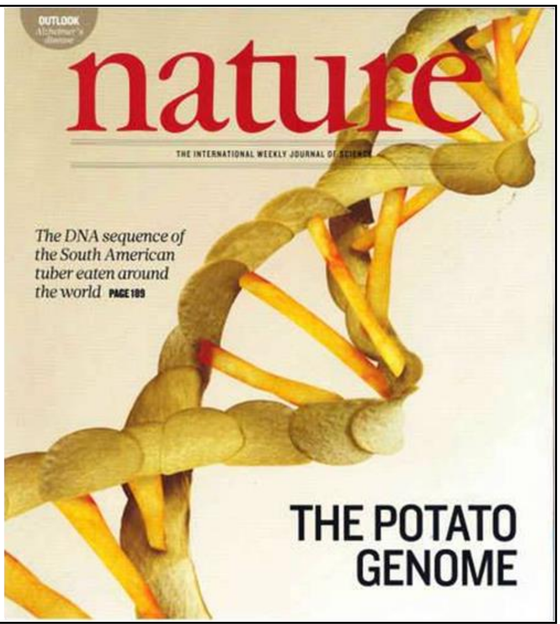
(i) Potato genome sequencing

The complex genome of potato has been deciphered by a consortium of 26 international institutes belonging to 14 countries. CPRI from India was the proud partner of this consortium. The complete potato genome has since been published in the high impact journal "Nature.

A hybrid approach including Sanger, Illumina, and 454 technologies was adopted for sequencing and assembly of 727 Mb which constitutes about 86% of the complete potato genome. A total of 39,031 protein-coding genes have been predicted in the sequence out of which about 800 genes encode disease-resistance related proteins (Xun et al. 2011). The sequence information will lead to identification of candidate genes and their markers which will be utilised for improving agronomic traits of potato, such as improved quality, yield, heat tolerance and disease resistance. It will also reveal new insights into the potential mechanisms of tuber initiation and development, host-parasite interaction, abiotic stress tolerance mechanism etc.



A concise diagram of potato genome

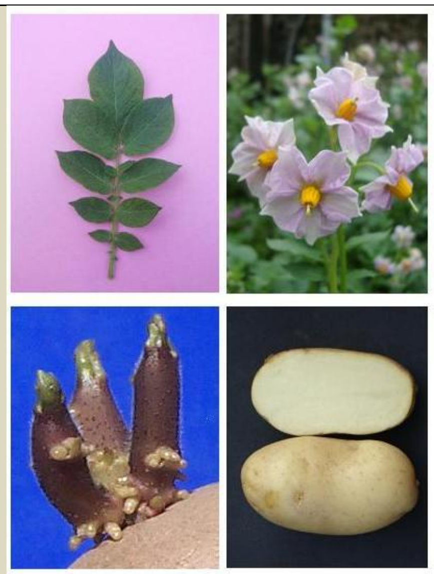


Cover page of Nature issue

(ii) Development of new potato varieties

Developed and released 11 potato varieties possessing combination of important agronomic traits *viz.* late blight resistance (3), heat tolerance (1), processing quality (4), multiple resistances to diseases (5) and 10-22% increased yield. Salient features of these varieties are given below:

Kufri Himalini	Kufri Girdhari	Kufri Surya
		
Adapted to North Indian Hills Yield potential of 35 t/ha Resistance to late blight (Joseph *et al.*, 2007)	Adapted to Indian Hills Yield potential of 35 t/ha Extreme resistance to late blight (Joseph *et al.*, 2011)	Adapted to **Warmer regions/seasons** Yield potential of 40 t/ha Resistance to **hopper burn, mite, wart and tolerant to heat** (Minhas *et al.*, 2006)
Kufri Himsona	**Kufri Sadabahar**	**Kufri Chipsona-4**
		
Adapted to Hills (Processing variety) Yield potential of 35 t/ha Resistance to late blight, wart (Pandey *et al.*, 2008)	Adapted to **UP and adjoining areas** Yield potential of 40 t/ha Resistance to late blight, early bulker (Pandey *et al.*, 2008)	Adapted to **Plateau, West-Bengal and Madhya Pradesh** Yield potential of 40 t/ha Resistance **to late blight, medium maturity, suitable for chips & flake** (Annual Report 2009-10, pp.35)
Kufri Chipsona-3	**Kufri Khyati**	**Kufri Frysona**

		
Adapted to North Indian plains Yield potential of 35 t/ha Resistance **to late blight, Suitable for making chips and French fries** (Pandey *et al.*, 2006)	Adapted to North Indian plains Yield potential of 40 t/ha Resistance **to early and late blight, early bulker, suitable for early planting.** (Kumar *et al.*, 2009)	Adapted to North Indian plains Yield potential of 40 t/ha Resistance **to late blight and wart, suitable for making French fries** (Singh *et al.*, 2010)

Kufri Neelima	**Kufri Gaurav**
	
Adapted to Southern Hills Yield potential of 30 t/ha Resistance to early blight, late blight and cyst nematode (Annual Report 2009-10, pp.107)	Adapted to North Indian plains Yield potential of 40 t/ha Moderate resistance **to late blight, High nutrient- use efficiency** (Annual Report 2009-10, pp.31)

(iii) Developed improved genetic stocks

Developed & registered 8 improved breeding lines as elite genetic stocks having earliness, resistance to pest & disease and frost tolerance.

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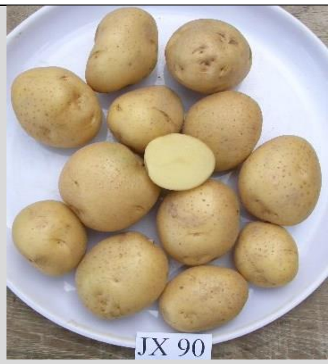
<td>
</td>
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<tr>
<td>Acc. Name: JX 123
Registration No. INGR 06021
Characters: earliness and resistance to early blight
(Kumar et al., 2006)</td>
<td>Acc. Name: JN 189
Registration No. INGR 07040
Characters: Resistant to leaf hopper burn and potato stem necrosis tospo virus
(Singh et al., 2008)</td>
<td>Acc. Name: JX 90
Registration No. INGR 09069
Characters: Combined resistance to late blight and early blight
(Annual report 2009-10, pp.30)</td>
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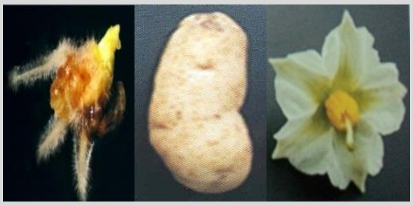
<td></td>
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<tr>
<td>Acc. Name: D4
Registration No. INGR 09067
Characters: Male fertile androgenic dihaploids of JTH/C107 with mutate white flowers
(Sharma et al. 2010)</td>
<td>Acc. Name: C-13
Registration No. INGR 09068
Characters: Male fertile, dwarf androgenic dihaploids of K.Chipsona-2 with high resistance to late blight and bushy appearance
(Sharma et al. 2010)</td>
<td>Acc. Name: SS-1725-22
Registration No. INGR 09121
Characters: Frost tolerant diploid clone of diploid wild species Solanum spegazzinii.
(Luthra et al., 2010)</td>
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<tr>
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<td colspan="2"></td>
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<tr>
<td>Acc. Name: SS 2040
Registration No. INGR 09120
Characters: Frost tolerant clone of cultivated tetraploid potato species Solanum tuberosum ssp. andigena.
(Luthra et al., 2010)</td>
<td colspan="2">Acc. Name: Triplex clone (YY 6/3 C-11)
Registration No. INGR10143
Characters: Possess Potato virus Y (PVY) extreme resistance gene Ryadg in Triplex (YYYy) condition. As progenitor this genotype will produce 96% progeny resistant to PVY.
(Annual report 2010-11, pp. 45)</td>
</tr>
</table>

iv. **Potato germplasm repository**

(a) Added 481 accessions of cultivated potatoes and 271 accessions of 47 wild species in the national active germplasm repository from Europe and America.

Accessions were evaluated for agronomic traits, abiotic and biotic stresses (adaptability, late blight, bacterial wilt, stem necrosis, viruses (PVX, PVY, PVS, PVA, PVM, PLRV, PALCV), leaf hopper and mites, potato tuber moth, cyst nematodes, keeping quality, chipping, vitamin C, heat, water and nutrient use efficiency and promising accessions for each trait were identified/documented. Till date, about 50 potato varieties have been released by CPRI using the germplasm lines available in its repository (Annual reports (2006-10); Kumar *et al*., 2005; Kumar *et al*., 2008).

In-vitro germplasm repository at CPRI Shimla

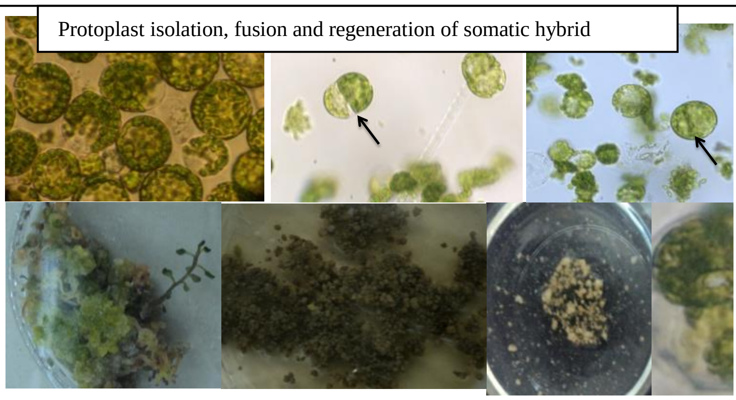
(b) Developed and characterized andigena core collection of 78 accessions out of 740 accessions using phenotypic and molecular markers (SSR).

The core collection of Andigena germplasm was developed by recording data on 21 traits of 740 accessions. The data was analyzed by Power Core software and 78 accessions representing total diversity was constituted as core collection. In subsequent year the data were analyzed by SPSS for cluster analysis. Based on three sampling strategies within cluster the optimum core set of 78 accessions was constituted. Power core was found to be the best method for core set analysis (Annual Report 2010-11).

v. **Gene prospecting through somatic hybridization**

Developed two interspecific somatic hybrids of potato *Solanum tuberosum* dihaploid C-13 (+) *S. etuberosum*, and C-13 (+) *S. pinnatisectum* resistant to Potato Virus Y and late blight through protoplast fusion to overcome the sexual barriers imposed by difference in ploidy and endosperm balance number (EBN).

Protoplast isolation, fusion and regeneration of somatic hybrid

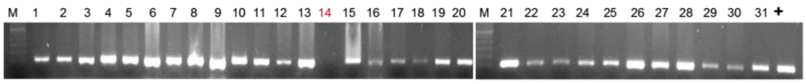


Phenotypic characters of a somatic hybrid and its parentsMany novel genes for late blight resistance, virus resistance, high dry matter content and other useful traits are available in diploid wild potato species like *Solanum pinnatisectum, S. etuberosum, S. cardiphyllum, S. acaule, S. brachistotrichum, S. jamesii, S. polyadenium, S. stoloniferum* etc. that are sexually incompatible with cultivated potato. To overcome this sexual barrier, somatic hybrids of those wild species with cultivated potato have been developed and characterized. The derived tetraploid genotypes can be exploited as pre-breeding material for introgression breeding (Sarkar *et al.* 2011; Tiwari *et al.* 2010).

Phenotypic characters of a somatic hybrid and its parents

vi. Marker assisted pre-breeding

A unique parental line having extreme resistance gene ... developed through marker assisted pre-breeding which has been registered as INGR 10143 by the Plant Germplasm Registration Committee of ICAR.



Segregation of SCAR marker in the progeny of test cross, QB/A 9-120 x Triplex clone

Severe inbreeding depression and tetraploid nature of cultivated potato, preclude development of homozygous parental line. Therefore, marker assisted selection (MAS) was used to develop a unique parental line having PVY extreme resistance gene (Ry_{adg}) in triplex state. This clone can be used as a parent in breeding programme for PVY resistance, since almost all the progeny derived from any cross with this parent will have at least one Ry_{adg} allele conferring extreme resistance to PVY (Annual report 2010-11, pp. 45).

vii. Gene cloning

Fourteen genes/promoters possessing important traits were cloned for use in genetic transformation studies without any IPR obligation.

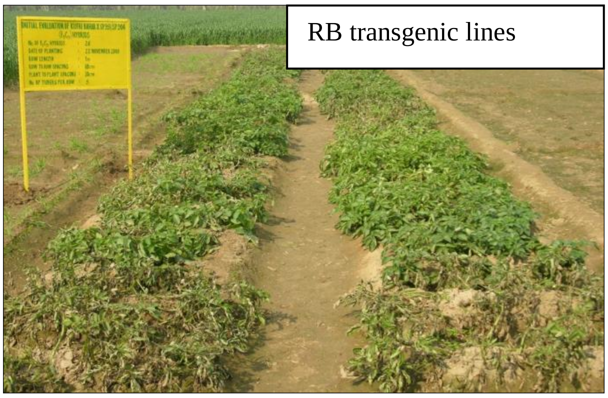
The following genes and genetic elements have been cloned in the institute and are being used for genetic transformation work :

Sl. No.	Gene/Promoter	Source organism/Variety	Trait
1	*cry1Ab*/GBSS	*Bacillus thuringiensis* (Synthetic)	Tolerance to potato tuber moth
2	*cry9Aa2*/CaMV35S	*Bacillus thuringiensis* subsp. *galleriae*	Tolerance to potato tuber moth
3	*osmotin*/CaMV35S	*Solanum chacoense*	Tolerance to late blight and salinity
4	*CP*/CaMV35S	Potato leaf roll virus	Resistance to potato leaf roll virus
5	PTGS construct of *MP*/CaMV35S	Potato stem necrosis virus	Resistance to potato stem necrosis virus
6	$glgC^{m}$/CaMV35S	*E. coli*	Increase in starch quantity
7	*AmA1*/CaMV35S &	*Amaranthus*	Improvement of protein quality

	AmA1/GBSS	*hypochondriacus*	and quantity
8	*inhh*/CaMV35S & *inhh*/GBSS	Tobacco	Reduction of cold-induced sweetening
9	RNAi construct of vacuolar *invertase*/ CaMV35S	Potato	Reduction of cold-induced sweetening
10	RNAi construct of *GBSS*/CaMV35S	Potato	Improvement of starch quality
11	RNAi construct of GA_{20}*oxi*/CaMV35S	Potato	Dwarf potato
12	RNAi construct of rep gene	Potato apical leaf curl virus	Resistance to potato apical leaf curl virus
13	Plastid transformation vector (pSKC21)	Tobacco/ *Bacillus thuringiensis* subsp. *galleriae*	Resistance to tuber moth
14	Gene cassettes with fused *cry1Ab+cry1B* genes	*Bacillus thuringiensis*	Resistance to tuber moth

viii. Transgenics for tailor-made variety development

Developed seven different events of transgenic potatoes with important agronomic traits viz., late blight durable resistance, reduction of cold induced sweetening, high protein content, resistance to Potato Virus Y, Potato Apical Leaf Curl Virus, Potato Tuber Moth, and altered plant architecture.



Though the above traits are agronomically desirable, generally they cannot be manipulated by conventional breeding. Genetic engineering technique was, therefore, exploited for developing designer varieties with the following specific traits.

Target trait	**Gene/Construct (source)/IPR issues**	**Status**
Late blight resistance	*RB* of *Solanum bulbocastanum*/ MTA with ABSPII, Cornell University	Promising transgenic genotypes expressing the RB gene and conferring field resistance to late blight have been identified for hills and plains. BRL-1 trial with promising lines in progress (Shandil *et al.* 2008).
Reduction of cold induced sweetening	Invertase inhibitor gene from tobacco (*ntinhh*)/Own construct	One promising transgenic line of Kufri Chipsona-1 with excellent cold-chipping attributes and no yield reduction has been identified. BRL-1 trial with promising lines in progress.
Increase in protein content	*AmA1* gene of *Amaranthus hypochondriacus*/	One transgenic line each of Kufri Chipsona 2 and Kufri Badshah with higher protein content and improved protein quality have been identified. Five

	Patented gene of NIPGR, New Delhi	confined yield trials completed (Chakraborty *et al.* 2010).
Dwarf architecture	RNAi for *GA20-oxidase1* gene/Own construct	Positive transgenic lines identified; glass house evaluation showed reduction of plant height in 20 transgenic lines.
Resistance to PVY	CP gene/Own construct	Positive transgenic lines identified by molecular analysis; glass house evaluation showed very good level of PVY in CP sense transgenics .
Resistance to Potato Apical Leaf Curl Virus	Rep gene/Own construct	Positive transgenic lines of Kufri Pukhraj identified by molecular analysis; glass house evaluation showed very high level of PALCV resistance in two transgenic lines (Tomar *et al.* 2011).
Resistance to potato tuber moth	Synthetic *cry1Ab* gene (ICAR property) driven by GBSS promoter	Positive transgenic lines identified; glass house evaluation showed very good level of resistance to potato tuber moth in one transgenic line of Kufri Badshah (Kumar *et al.* 2009).

Non-transgenic Kufri Chipsona 1

Transgenic Kufri Chipsona 1

ix. Development of meiotic tetraploid (MTs) for introgression of late blight resistance

Developed 92 meiotic tetraploids using unilateral sexual polyploidization (USP) method involving three wild species (*S. chacoense, S. microdontum* and *S. verrucosum*). Two of these meiotic tetraploids are in advanced breeding trials (F_1C_6) besides using them as parental material in late blight breeding programme.

Development of parents of MT's

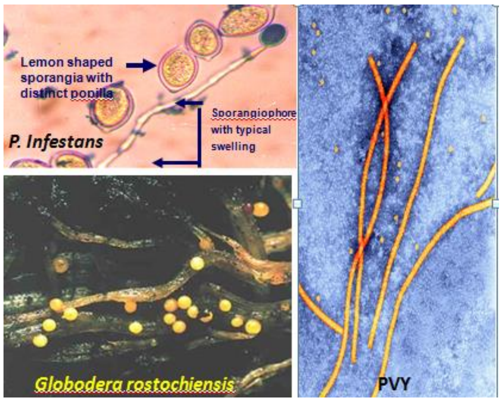
x. Development of multiple disease resistant potato hybrids

Developed two advanced hybrids (LBY-15 & LBY-17) having combined resistance to *late blight and Potato Virus Y using* marker assisted selection approach. These are being evaluated in multilocational trials under AICRP (Potato).

Two indigenous, highly late blight resistant genotypes, *viz*., Kufri Girdhari and QB/A9-120 and germplasm accessions YY-3, YY-6 and YY-13 having PVY extreme resistance gene in duplex condition were used as parental lines. The advanced clones were selected on the basis of SCAR marker and immunological response besides performance under field conditions (Bhardwaj *et al*., 2007; Kaushik *et al*., 2008; Annual report 2010).

xi. Gene stacking for multiple disease resistance

Identified seven potato genotypes having multiple resistance genes for Late Blight (*R1* & *R3*), Potato Virus Y (*Ryadg*) & Cyst Nematodes (*HC*, *H1* & *Gro1*) using molecular markers.

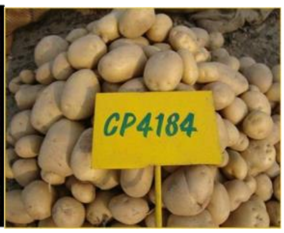


Potato genotypes possessing late blight resistance genes, R1 and R3a were characterized through molecular markers. Based on the MAS results parental lines possessing these genes were hybridized and genotypes with combined (R1 and R3a) genes in single host background were developed. Further, the potato genetic stocks possessing resistance to late blight (*R1*, *R2*, *R3*, *Cos A-29 & 30* and *R8*), Potato Virus Y (*Ryadg*) and Golden cyst nematode (*HC*, *H1* and *Gro1*) have been identified through molecular markers for developing potato varieties with combined resistance to all the three diseases (Bhardwaj *et al*., 2011).

xii. Development of heat tolerant genotypes

Identified four heat tolerant clones with good agronomic traits. These have been introduced into AICRP for multi-location testing.

Based on superior performance under early planting conditions (heat stress) at Ladol in Gujarat, four CIP advance clones namely CP4054, CP4184, CP4197 and CP4206 were identified and introduced in AICRP during 2011 for multi-location testing (Singh *et al*.,2010)

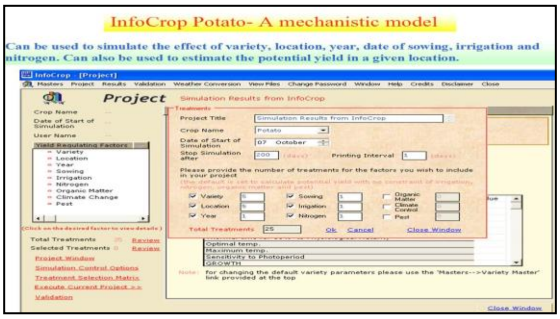


xiii. Development of decision support systems (DSS)

Developed nine Decision support systems/tools for recommending location specific Best Management Practices (BMPs) for diverse agro ecological conditions under which potato is grown in India as well as extend support to improve efficiency of crop improvement programmes.

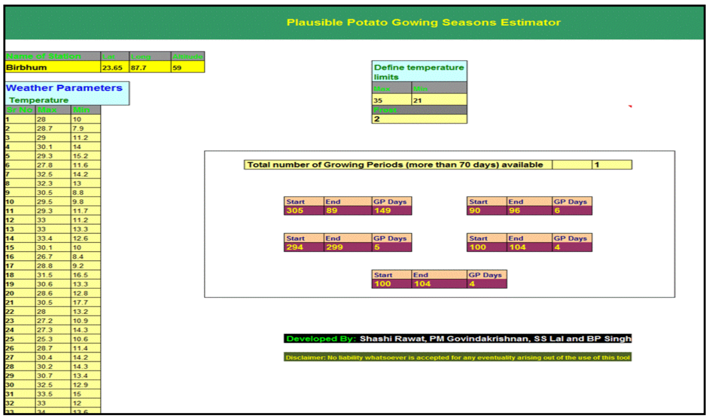
a) A potato crop growth model "INFOCROP-POTATO" was developed. This has enabled estimation of yield gaps and develop Best Management Practices (BMPs)

The model simulates the phenology of the crop and computes the amount of intercepted radiation and the total biomass yield based on radiation use efficiency consequently the tuber yield based on harvest index. It also simulates the crop growth processes, soil water, nitrogen and carbon dynamics, and crop-pest interactions for generating model based site specific recommendations. The model is being extensively used for generating BMPs and also pre-harvest yield forecasting of potato production and also for climate change impact and adaptation studies (Govindakrishnan *et al.*, 2007, Singh *et al.*, 2008a, Govindakrishnan *et al.*, 2008a, Singh *et al.*, 2009a).

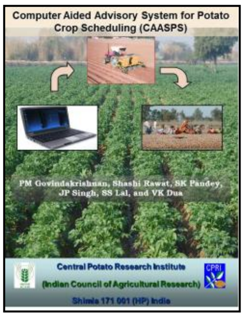


b) Plausible Potato Growing Seasons Estimator (PPGSE) developed for spatial and temporal diversification of potato cultivation

This tool estimates the number of growing seasons and their duration for any location in India. Algorithms to screen the maximum and minimum temperature records of any location according to threshold limits set by the user and extract those periods which meet the criteria continuously for a period of more than 70 days are displayed along with the start and end of the season (Rawat *et al.*, 2011).



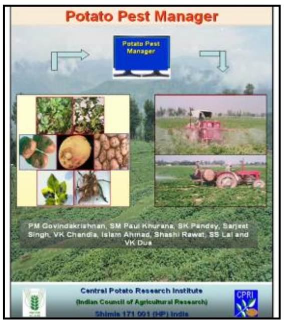
c) Computer Aided Advisory System for Potato Crop Scheduling enables farmers to use information on climate and physiology to choose best date of planting, variety and fix harvesting date.



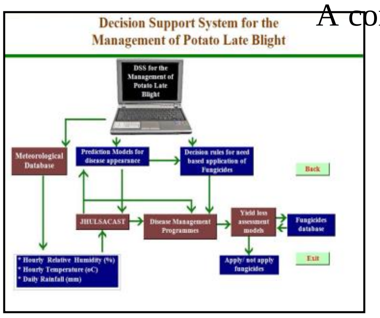
This tool consists of a database of “INFOCROP-POTATO” model derived expected yields of 10 varieties planted at 5 dates of planting and at 4 crop durations *viz.* 60,70,80 and 90 DAP for 800 locations in India. It helps the grower to select the suitable potato cultivar on the basis of date of planting and duration of the crop for his area/region (Govindakrishnan *et al*., 2008a, Govindakrishnan *et al*., 2008b).

d) Potato Pest Manager brings expert knowledge on plant protection within the reach of farmers.

This decision support system elicits information on symptoms and epidemiology interactively and thus helps in correct identification of the pest/disease problem and then gives situation specific recommendations for their control (Govindakrishnan *et al*., 2008b).



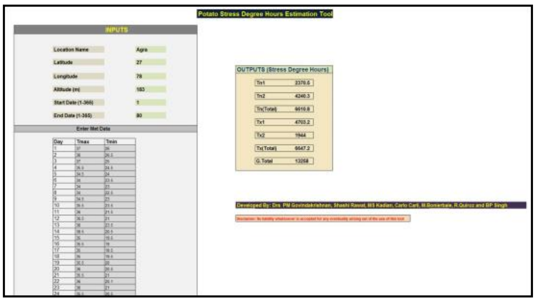
e) Decision Support System for management of late blight



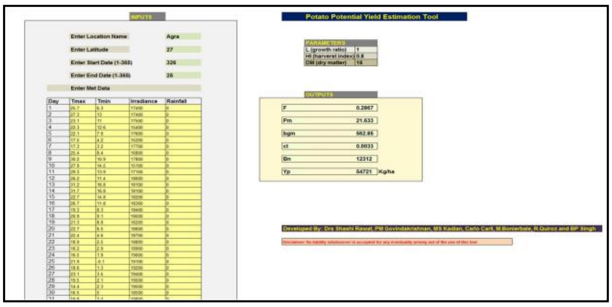
A computerized Decision Support System for management of late blight has been developed. The DSS has three components i.e. decision rules for prediction of first appearance of late blight, decision rules for need based fungicide application, and yield loss assessment model. The JHULSACAST model would predict first appearance of late blight well in advance. Decision rules for need based application of fungicides ensures timely fungicide spray before the actual onset of the disease and thus helps in avoiding unnecessary sprays thereby reducing the cost of cultivation. Yield loss assessment model gives an idea whether fungicide application is profitable or not. This system has already been validated for western Uttar Pradesh (Govindakrishnan *et al*., 2009b, Bhat *et al*., 2008).

f) Potato Temperature Stress Degree Hours Estimation tool - a tool to help breeders to characterize environments for effective targeting of genotypes.

This tool screens the temperature database and estimates the duration during each 24 hour period during which the ambient temperatures are above the optimum temperatures and this is summed over the whole growing period. This is indicative of the magnitude of heat stress at any location/season. This tool is useful in evaluation of genotypes tolerant to heat stress and also for identifying their target sites for deployment and in manipulating date of planting with minimum stress (CPRI Newsletter, July 2011).



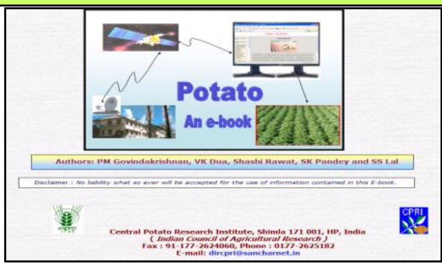
g) Potato Potential Yield Estimation tool – A tool to estimate the yield gap



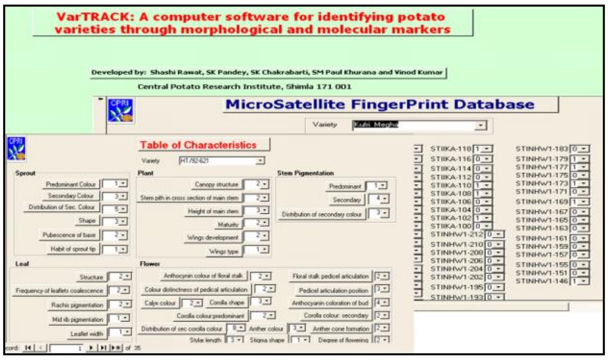
This tool estimates the potential potato yield based on the FAO Agro-ecological Zones model for any location on the basis of weather data, geographical location, and season. It provides information on the expected yield and thus the yield gap which is useful for developing agro-techniques to narrow the yield gap (CPRI Newsletter, July 2011).

h) Potato E-book brings potato information to a wide range of clientele interested in potato

This tool contains information on the various aspects of potato production arranged at different hierarchical levels of complexity so as to cater to a wide range of users (Govindakrishnan *et al*., 2009a, Rawat *et al*., 2009).



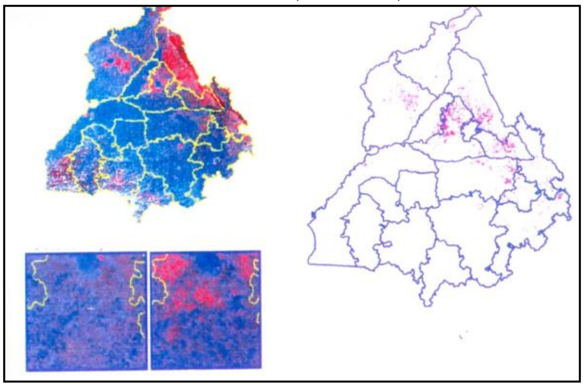
i) VarTRAC: A computer software for identifying potato varieties through morphological and molecular markers



The tool has been developed at CPRI for speedy identification of a variety based on 50 different morphological attributes and DNA fingerprints based on 127 alleles from 4 micro-satellite markers (Rawat *et al*., 2009).

j) **Acreage and production forecast of potato**

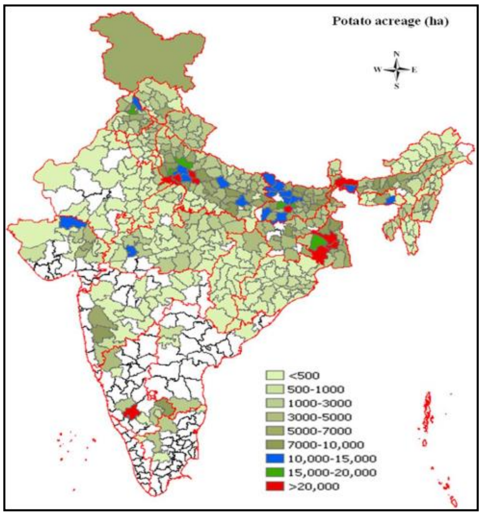
Methodology developed for regional level pre-harvest potato acreage and production forecast using remote sensing data, GIS and crop modeling for effective policy interventions. A methodology for potato acreage estimation through remote sensing and GIS using Advanced Wide Field Sensor (AWiFS) data from Indian Remote Sensing Satellite IRS P6 was standardized in collaboration with Space Applications Centre (ISRO), Ahmedabad, which is now included in the FASAL (Forecasting Agricultural output using Space, Agro-meterology and Land-based observations) programme of Govt. of India. For production estimates, outputs from INFOCROP-POTATO model are used (Dua *et al*., 2007, Govindakrishnan *et al*., 2007).



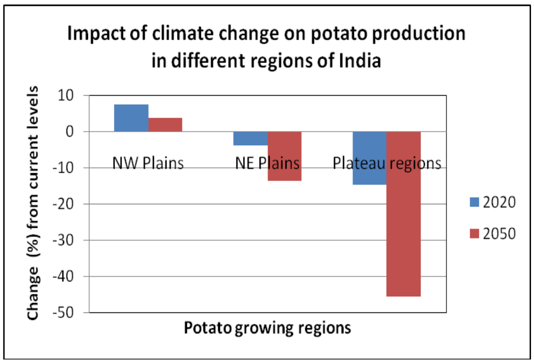
k) **Thematic maps**

Thematic maps on potato statistics and characteristics of potato growing environments makes data meaningful for use in decision making.

- Thematic maps of potential yield of potato, areas suitable for growing potatoes for processing, areas prone to frost, high temperature stress etc. in different parts of the country were prepared.
- The possible areas which are climatically suitable for raising potato crop in the kharif season were mapped.
- The suitable sites for seed potato production in the north eastern states were identified through GIS (Rawat et al., 2007, Rawat et al., 2008).



xiv. **Impact of climate change on potato worked out**



The impact of climate change on potato in different regions was assessed using INFOCROP-Potato model. The yield is estimated to be severely reduced in southern and peninsular India (9-47%), moderately reduced in Indo Gangetic plains (3-13 %) and slightly increased (3-7%) in the north western Indo Gangetic plains due to milder winters. The potato production in India may decline by 2.61 and 15.32 % in the year 2020 and 2050, respectively. The least vulnerable region will be North-western plains (Punjab, Haryana and areas of western UP and northern Rajasthan) with possible increase of 3.46 to 7.11% and the most vulnerable region will be West Bengal, plateau regions and other areas in south India with a possible decrease of 9 to 55% in productivity (Singh *et al*., 2008, Singh *et al*., 2009).

xv. Agro-techniques for processing potatoes

Technologies for production of processing potatoes standardized.
Agro-techniques *viz* optimum date of planting (2nd week of October in North-western plains and 3rd week of October in West-central plains), crop geometry (67.5 x 20 cm), nutrient requirement (270 kg N, 80 kg P_2O_5 and 150 kg K_2O/ha; with 50% N and full PK to be applied at planting and rest at earthing up) and water management (irrigation at 20 mm cumulative pan evaporation) practices were standardised (Kumar *et al*., 2007 and Kumar *et al*., 2008).

xvi. Micro-irrigation and fertigation in potato

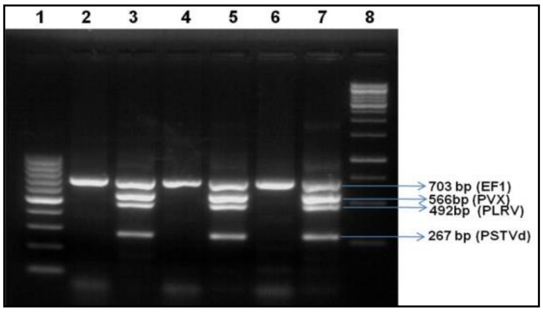
Micro-irrigation and fertigation technology standardized to make potato production feasible in the future era of water shortage.
In order to economise on water and fertilizers, micro irrigation and fertigation techniques have been developed and standardized for potato, which economize on water by 40-50% and fertilizer NPK by 25-30% with 25-30% higher yields, over furrow irrigation method (Singh and Singh, 2007, Singh *et al*., 2010).

xvii. Farm mechanization

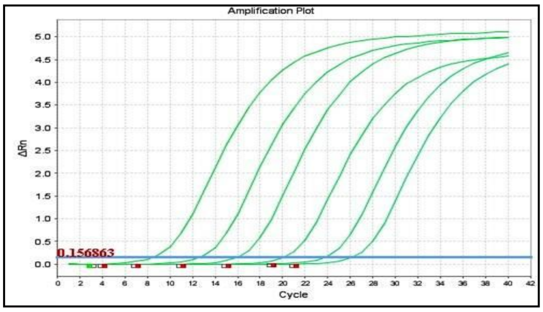
To make potato production less labour intensive, increase economic viability and ensure timely operations various farm machinery/implements were developed. These include seed treatment system, French fry cutter, Potato grader and inter culturing machines. (Annual Reports, CPRI, Shimla 2006-07 to 2010-11, Singh *et al*., 2008d).

xviii. Development of molecular diagnostics of potato pathogens

a. **Developed PCR based protocols for detection of potato viruses** (Gawande *et al.*, 2007; Kaushal *et al.*, 2007 & 2010), **bacterial wilt** (Grover *et al.*, 2009) **and late blight pathogens** (Sharma *et al.*, 2010)**, in seed stocks.**

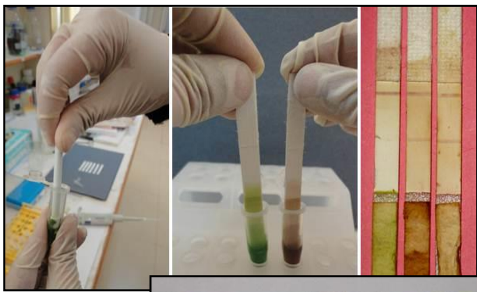


Multiplex RT-PCR for detection of PVX, PLRV and PSTVd



Real Time RT-PCR for quantification of PVY

b. **Developed portable dipstick kits for detection of five major potato viruses at field level using gold nanoparticles :** These kits are portable and easy to use by any stakeholder including farmers (Chakrabarti *et al.*, 2010). This will help in improving the health of potato crop.



Procedure to use

xx. PGPR formulation Bio-B5

Identified and patented a biofertilizer-cum-bio-pesticide formulation (Bio-B5) for eco-friendly management of soil- and tuber-borne diseases as well as for yield enhancement.

It consists of a strain of *Bacillus subtilis* (IMI No. 360643) that releases three antibiotic metabolites namely, Iturin, Viomycin, and Chalcone. The formulation has a killing effect against major pathogen. It also inhibits growth of *Ralstonia solanacearum*, the cause of bacterial wilt of potato against which no chemical or resistant variety is effective till date (Sunaina and Ajay 2005, 2007).

xxi. Molecular profiling of potato pathogens

Revealed major population shift of *Phytophthora infestans* and *Ralstonia solanacearum* using molecular markers.

A major shift in the distribution pattern of *Phytophthora infestans* and *Ralstonia solanacearum* was detected through molecular characterization of samples collected from different agro-climatic zones of India. Results revealed that the 1a mt haplotype, which was detected in 2002, is gradually replacing the earlier Ib population (Chimote *et al.*, 2010). Similarly, molecular phylotyping of *Ralstonia solanacearum* revealed that the potato race (race 3/biovar 2), which was virtually absent in sub-tropical regions, is now establishing in Madhya Pradesh, West Bengal, and Karnataka (Grover *et al.*, 2006; Sagar *et al.*, 2010).

xxii. Management schedules for pests and diseases

Developed effective management schedules for emerging and re-emerging pests and diseases like white flies, aphids, potato tuber moth, late blight, and soil- and tuber-borne diseases.

xxiii. On-farm storage

Developed improved heap storage technology using CIPC to tide over market gluts.

An improved low cost heap storage technology integrating pre and post harvest measures viz., tuber maturity, haulm cutting, curing, early heaping, ventilation with perforated pipe and spraying of CIPC (isopropyl–N (3-chlorophenyl) carbamate) for sprout suppression was developed, demonstrated and validated for short-term storage to avoid market gluts. The technology was successfully demonstrated in several villages of Punjab and Uttar Pradesh and presently thousands of tonnes of potatoes are being stored on-farm in the states of Punjab, UP, MP, WB, Gujarat, Maharashtra and Karnataka (Mehta *et al*. 2011).

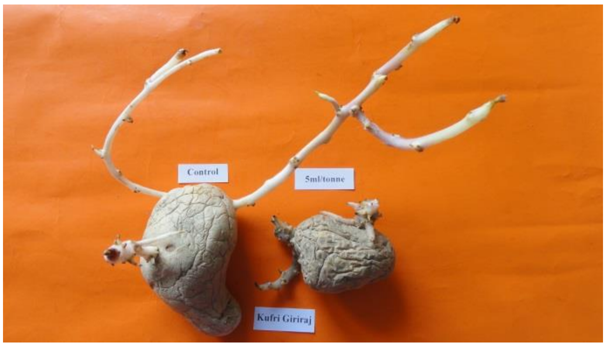
xxiv. Elevated temperature storage

Developed elevated temperature storage technology for enabling round the year availability of raw material to the processing industry.

Potatoes when stored at 2-4°C accumulate reducing sugars, taste sweet and produce dark coloured processed products. The Institute standardized the elevated temperature storage (10-12°C) technology using CIPC (chlorpropham) as sprout suppressant and optimized chemical maturity for getting best results in table and processing potatoes (Singh & Kumar, 2008). This revolutionized round the year availability of raw material to the processing industries. The technology helps save on electricity (40% compared to ordinary cold store), and is preferred over 2-4°C storage as potatoes stored at 10-12°C do not accumulate much sugars and fetch premium price of at least Rs 2/- per kg.

xxv. Management of seed dormancy

Prolonged seed dormancy by using 1,4 DMN and improved the seed quality under non-refrigerated hill situations.



In absence of refrigerated stores in hilly areas, potato seed is stored under diffused light conditions, which results in development of long and lanky sprouts by planting time. 1,4 DMN (1,4-dimethylnaphthalene), a naturally occurring substance present in potato tuber skin, when sprayed on seed potatoes stored under diffused light in hills, delayed dormancy release up to 120 days and resulted in healthy and vigorous sprouts by planting time (CPRI Annual Report 2010-11). The technology is being perfected for transferring to the end users.

xxvi. Potato tuber moth (PTM) management in non-refrigerated storage systems

Developed schedule for management of potato tuber moth under non-refrigerated storage condition.

In absence of refrigerated storages as in case of mid hills of Himachal Pradesh, farmers use rustic stores for avoiding distress sale at harvest and such conditions favour heavy infestation of potato tuber moth (PTM) during storage. Spraying of potatoes with CIPC (chlorpropham) prior to storage under these rustic stores drastically reduced the infestation of PTM (no infestation compared to 30% in untreated potatoes) in five villages of Kangra district and simultaneously resulted in 95% sprout inhibition, thereby enhancing the keeping quality also (Chandel *et al*. 2008, Chandla *et al*. 2008).

xxvii. Profiling of Indian potato varieties for phytochemicals, acrylamide and glycoalkaloids

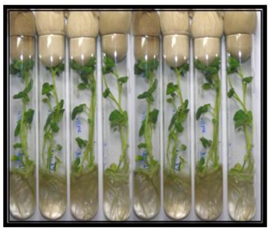
All Indian potato varieties were profiled for phytochemicals, acrylamide content and glycoalkaloids. This information is higly valuable from the stand point of nutritional qualities of potato. (CPRI Annual Reports 2008-09, 2009-2010, 2010-11)

xxviii. Delicious potato products developed

A large number of processed potato products including several non-fried and fried products were developed from potatoes. Amongst non-fried products, instant potato soup mix and potato custard powder are two such products, which have good shelf life, can be prepared instantly and have commercial value. The custard pudding prepared from potato starch and potato flour-starch combination (1:9) tastes equally good or better than the corn custard commercially available in the market.

xix. Hi-tech seed production system based on tissue culture technology developed that accounts for 40% of the breeder seed produced by CPRI

The high-tech seed production system through tissue culture was standardized and put to use for production of breeder seed, which accounts for 40% of the total breeder seed production by CPRI. (CPRI, Annual Report 2006-11)



Microplants

Microplants in net house

xx. Variety specific tissue culture protocols developed

The standard MS medium was modified for micropropagation of recalcitrant potato cultivar Kufri Jyoti. The modified medium contains increased level of ammonium nitrate from 20. 63 mM to 25.79 mM supplemented with GA_3 (0.58 µM) and NAA (0.1 µM) was found to be the best for *in vitro* multiplication of Kufri Jyoti. (Venkatasalam *et al* 2011).

xxi. Development of aeroponic system of seed production in country

The aeroponic system for potato seed production was developed and upscaled for commercial production of potato seed . This will avoid seed contamination and at the same time has increased the rate of seed multiplication four times to that of tissue culturally produced mini tubers. (Singh *et al*. 2010).

xxii. Technology adoption

Baseline surveys revealed the variable adoption of CPRI technologies at different places. The adoption level was highest in Punjab and least in Bihar. Among the individual technologies, integrated pest management practices (IPM) was the least adopted technology.

xxiii. Demand estimation for potato processing sector

a) Processing quality potato demand increased from 0.97 to 2.68 million t during 2005-06 to 2010-11.

b) Potato farmers are estimated to earn additional Rs 342 crores during these five years on account of growing processing potatoes.

c) Internal Rate of Return (IRR) to the research cost for developing Kufri Chipsona 1 and Kufri Chipsona 2 was estimated to be as high as 55%.

d) Present Net Worth (NPW) at 0%, 5% and 10% rate of interest was worked out equal to Rs 210.92 crore, Rs 96.85 crore and Rs 46.11 crore respectively.

e) Per hectare gross and net income for Kufri Chipsona 1 was higher than the average of potato farm by 22% and 30%, respectively and the benefit-cost ratio of Kufri Chipsona 1 was 1.91 while it was 1.61 for the average of all potato varieties grown on the farmers' fields in UP.