# Souvenir

A view of CPRI seed farm at Kufri, Shimla with portrait of Dr Ramanujam (inset)

*Symposium on*

# Potato Research towards National Food and Nutritional Security

**and**

# Dr S Ramanujam Birth Centenary Celebrations

**at CPRI, Shimla (HP)**

**October 2-3, 2003**

*Jointly organized by*

**Indian Potato Association**
**Central Potato Research Institute, Shimla**
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# *Souvenir*

Symposium on Potato Research towards National Food and Nutritional Security
and Dr S Ramanujam Birth Centenary Celebrations, 2-3 October, 2003, CPRI, Shimla

Edited by : SM Paul Khurana, SK Pandey & Brajesh Singh

Associates : JP Uniyal & Rajneesh Rajput

Published by Indian Potato Association, Central Potato Research Institute, Shimla 171 001 (HP)
Phone : 0177-2625073, Fax: 0177-26244601, E-mail: direcpri@bol.net.in, director@cpri.np.nic.in and
Printed at Malhotra Publishing House, B-6, DSIDC Packaging Complex, Kirti Nagar,
New Delhi-110 015, Ph.: 25157006, Telfax: 25934597, E-mail: mph@vsnl.com

# Symposium on Potato Research towards National Food and Nutritional Security and Dr S Ramanujam Birth Centenary Celebrations

## October 2-3, 2003

*Jointly organised by*

**Indian Potato Association, Shimla**

**Central Potato Research Institute, Shimla and**

**International Potato Center (SWCA), New Delhi**

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# Symposium on Potato Research towards National Food and Nutritional Security and Dr S Ramanujam Birth Centenary Celebrations

## October 2-3, 2003

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# Acknowledgements

On behalf of the Organising Committee and on my own, I wish to thank authorities of ICAR and International Potato Center (CIP), New Delhi for their kind co-operation, encouragement and facilities.

Grateful thanks are due to the *platinum sponsors*, National Horticultural Board and National Horticultural Research & Development Foundation and to the *gold sponsors*, Chambal Agritech and Frito-Lay India Ltd. for their kind and generous help as well as to the advertisers for their financial support.

Special thanks are also due to the members of the Advisory Committee, Mrs V Ramanujam and the entire family of Late Dr S Ramanujam including grand children for their valuable endowment for the Ramanujam Award and encouragement in many ways for the centenary celebrations.

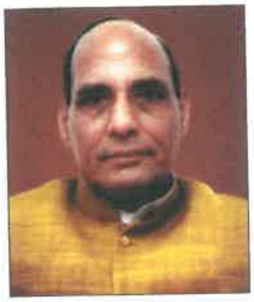
Kind help and co-operation received from Dr SK Pandey, Dr Shiv Kumar, Dr KC Sud, Dr Brajesh Singh, Sh RK Chauhan, Sh JP Uniyal, Sh Rajneesh Rajput, Sh DP Gautam, Sh Rajender and Sh SK Dey is also acknowledged, without which it would have not been possible to organise the symposium and centenary celebrations.

Thanks are also due to S/Shri Joginder Singh Thakur, RL Verma and HN Sharma for secretarial assistance.

I am also thankful to Sh Vinay Malhotra of MPH, New Delhi for his guidance in the designing and timely bringing out the special volume of Journal of Indian Potato Association and the Souvenir of the Symposium.

Dr SM Paul Khurana
Chairman, Organising Committee

# MESSAGES



राजनाथ सिंह
**RAJNATH SINGH**

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भारत सरकार
कृषि भवन
नई दिल्ली–110001
MINISTER FOR AGRICULTURE
GOVERNMENT OF INDIA
KRISHI BHAWAN
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# MESSAGE

I am pleased to know that Central Potato Research Institute (CPRI) is organizing a symposium on "Potato Research Towards National Food and Nutritional Security" and also celebrating the birth centenary of Dr. S. Ramanujam, its founder Director, at Shimla from October 2-3, 2003.

The research efforts at CPRI, especially in the last three decades, have resulted in development of improved potato varieties and generation of several technologies for its cultivation have placed India among the leading potato growing nations in the world.

I am confident that the deliberations of the symposium will yield suitable recommendations for giving further boost to potato production, its quality, exports and associated industry.

I wish the functions a grand success.

(RAJNATH SINGH)


डा. मंगला राय
सचिव एवं महानिदेशक
**DR MANGALA RAI**
Secretary & Director-General



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# MESSAGE

It is matter of great pleasure to see that Central Potato Research Institute (CPRI) is organizing a symposium on **"Potato Research Towards National Food and Nutritional Security"** at Shimla from 2-3 October 2003 in collaboration with the Indian Potato Association (IPA) and International Potato Centre (CIP) and also celebrating the birth centenary of Dr S Ramanujam, founder Director of this institute.

The technologies generated at CPRI have revolutionized potato production in the country. Even though India today is the third largest producer of potato in the world, we have still to realize the complete production potential of the crop. Potato is not just a vegetable but also a wholesome food and is being recognized as an important component of dietary intake to provide household food and nutritional security in the country. We need to diversify its usage. Further, we have to focus our research efforts towards development of suitable post harvest technologies to ensure safe storage, transport, processing and value addition so that huge annual losses of farm produce are prevented.

I am sure that the daliberations of the symposium will focus on some of the weaker areas and suggest suitable research intervention to overcome the constraints in potato production.

I convey my best wishes for success of the events.

**( MANGALA RAI )**

**Dated the 16th September, 2003**
**New Delhi**

**Dr Srinivasa Ramanujam**
(1903-1979)

# About Dr S Ramanujam

Dr Srinivasa Ramanujam was borne on October 2, 1903 at Varanasi near Salem (Tamil Nadu). He had his early schooling in Salem and Madras. He took his honours degree in Botany and Geology in 1925 and was awarded the MA degree of the Madras University in 1927. In 1935, he joined King's College, London and obtained his Ph.D. from the London University in 1937.

Dr Ramanujam began his professional career as a Research Assistant to the Paddy Specialist at Coimbatore. From 1938-1946, he worked as the Second Economic Botanist at the Indian Agricultural Research Institute, New Delhi. From 1949 to 1956 (except for one year), he was the Director, Central Potato Research Institute, then located at Patna. Subsequently, he joined as the Director of Research, Department of Agriculture. Government of Bihar, where he organized and guided all aspects of agricultural research in the state till 1966. After retirement, he settled down in Bangalore. Even after his retirement his expertise was much sought after and he continued to be associated with several expert committees of ICAR, INSA, Government of Bihar and the University of Agricultural Sciences, Bangalore. Dr Ramanujam passed away on 9 June, 1979 at Bangalore.

Dr Ramanujam was one among the earliest scientists in India to initiate cytological studies under the overall leadership of Dr K Ramiah, the then Paddy Specialist, Coimbatore. Dr Ramanujam, in close and equal collaboration with his colleague, Dr N. Parthasarathy, FNA, made significant contributions to the cytology of rice. For the first time, haploids, triploids and tetraploids were identified in rice their cytological and breeding behaviour studied and their, utility in crop improvement evaluated. The finding that twin/polyembryonic seed1ings could be of different ploidy levels was an important contribution. This group also initiated mutation breeding in rice using X-rays; they identified ring formation as a result of translocation, chlorophyll deficiency and asynaptic plants in the mutagenised material.

Dr Ramanujam carried out in London his PhD work on rice, the results of which were incorporated in three papers. In particular, he studied the cytological behaviour of an interspecific hybrid, *Oryza sativa* x *Oryza officinalis* and the progeny, including triploids and aneuploids (2n + 1, 2n + 5) derived therefrom and elucidated the inter-relationship between the two species.

On joining the Indian Agricultural Research Institute in 1938, Dr Ramanujam took up the systematic exploitation of colchipolidy induction announced by Blakeslee and Avery in the previous year (1937). Polyploids of a large number of crop plants were induced by him and his colleagues and students; the autopolyploids thus produced were cytologically analysed, their breeding behaviour followed and utility assessed. Most fruitful was the pursuit of

induced amphidiploidy, obtained by colchicine treatment of interspecific crosses. In these amphidiploids, fertility was generally restored. By a detailed study of the amphidiploids obtained from the interspecific cross, *Brassica campestris* x *B.nigra,* his group was able to elucidate the origin of the naturally occurring taxon, *Brassica juncea,* a widely cultivated oilseed crop of India. From the interspecific cross in sesamum *(Sesamum orientale* x *S. prostratum).* An entirely different plant, created as new species, *sesamum indicatum,* was obtained; this amphidiploids proved useful in the transfer of disease- resistance from the wild S. *prostratum* to the cultivated oilseed, *S. orientale.*

Dr Ramanujam as the first Director, was responsible for organizing the Central Potato Research Institute, guiding it at its formative stage and putting research on potato in India on a strong foundation. Under his able guidance, the Institute contributed strongly to the betterment of the potato crop in India, through development of improved varieties and improved management practices. After thorough screening of a large number of true seedlings obtained through hybridization, several improved varieties of potato suitable for cultivation in the plains and hills of northern India were developed. An important idea developed by him of stabilizing workable homogeneity in populations raised from true seed to provide the commercial crop, is now being extensively pursued as an answer to degeneration problem inherent in tuber reproduction. The results of the researches carried out by Dr Ramanujam and students under his guidance have been incorporated in a number of papers published in leading scientific journals.

Dr Ramanujam was invited by the Bihar Government to help implement their decision to revamp agricultural research in that state. In the ten year period between 1956-66, Dr Ramanujam devoted himself to planning, coordinating and developing agricultural research in the State of Bihar. He initiated and supervised the setting up of four Regional Research Institutes, encouraging multidisciplinary research. Special mention may be made of his emphasis on comprehensive studies on the acid soils which cover a large portion of the state.

Dr Ramanujam was a member of the Genetical Society of Great Britain and of the British Association for the Advancement of Science. He became a fellow of Indian National Science Academy in 1948. He was elected President of the Botany Section of the Indian Science Congress in 1952. He was the founder member of the Indian Society of Genetics and Plant Breeding of which he also became the Secretary and President in subsequent years.

*Keynote address*

# Role of potato in food and nutritional security in developing countries with special reference to India

**Mangala Rai**
*Secretary, Department of Agricultural Research and Education*
*and*
*Director General, Indian Council of Agricultural Research*

## About Dr Mangala Rai

DR MANGALA RAI, obtained Masters degree in Genetics and Plant Breeding on merit scholarship in 1969 and Ph.D degree on UGC fellowship from the Benaras Hindu University in 1973. His career started as Junior Plant Breeder in April 1973 and presently he occupie the position of Secretary, DARE & Director General, ICAR. His main priorities include promoting inter disciplinary research in thematic areas, diversification, human resource development and institutional capacity building to make India's National Agricultural Research System strong and self reliant.

Dr Rai has served with distinction in several responsible positions and has made significant contributions that have proved decisive in shaping agriculture of our country. His past responsibilities included, DDG (Crop Sci.) from 1997-2002, ADG (Policy & Pers. Plan.) 1995-1997; ADG (Seeds) 1987-1994, Project Coordinator (Linseed), etc. He was also entrusted with important additional responsibilities, such as Director (Oilseeds Technology, TMO), National Director (NATP) and Agriculture Commissioner, GoI. As Chairman, National Technical Coordination Committee (Rice-Wheat) fostered the co-evolution of the resource conserving technologies (RCTs) with international Rice-Wheat Consortium (RWC). He has successfully completed an assignment as consultant with the Food and Agriculture Organization of the United Nations in planning seed security system in Ethiopia.

He has to his credit over 200 papers/presentations in important journals/platforms covering various facets of agricultural sciences and policy papers relating to GATT, WTO and IPR.

In recognition of his immense contribution to the cause of agricultural research and education, Dr Rai has been conferred with several awards including the D.Sc (*Honoris causa*).

It is gives an immense pleasure to be with you today morning to participate in the symposium on "Potato Research Towards National Food and Nutritional Security" and also function to celebrate the birth centenary of Dr S Ramanujam, founder Director, of CPRI.

**Dr Ramanujam** served as Director, CPRI for about 9 years and laid a firm foundation for potato research, production technology including seed production and varietal development in India. It is a pleasant coincidence that he was also born on October 2, the date on which India was blessed with birth of Mahatma Gandhi and former Prime Minister Shri Lal Bahadur Shastri Ji who shared a great concern for the developing of agriculture and the farming community in the country. Gandhi Ji often expressed that India lived in villages and felt that India could develop only if villages were developed. Shastri Ji highlighted the importance of agriculture by equating it with the national security in his famous slogan "Jai Jawan, Jai Kisan". Dr Ramanujam made significant research contributions to strengthen agriculture in the country. From 1946-1956 (except for one year), he was the Director, Central Potato Research Institute, then located at Patna. Even after his retirement his expertise was much sought after and he continued to be associated with several expert committees of ICAR, Government of Bihar and the University of Agricultural Sciences, Bangalore. I take this opportunity to pay my respectful tributes to Dr Ramanujam.

## FOOD AND NUTRITIONAL SECURITY TO PROSPERITY

The prevalence of malnutrition and hunger leads to the loss of human potential and casts shadow on the national prosperity. In a predominantly agrarian society like India, agriculture can provide a firm foundation for broad-based economic growth and prosperity.

Strong and ecologically sustainable agriculture is essential to generate employment opportunities, boost income and economic growth in both rural and urban areas. Besides contributing to overall rural development, it improves the national ability to meet growing regional and global food needs, and also conserves natural resources. Given that so many women, indigenous groups, and poor people participate directly in agricultural production, processing, and distribution, a vibrant food and agricultural system will also promote social and economic equity. Agriculture thus becomes a unique sector of the economy wherein the benefits of modernization will be so widely distributed and so be supportive of the poor.

## PRODUCTION TO CONSUMPTION SYSTEM OF OPERATION

It is widely accepted that agriculture in India has made tremendous progress as a result of national R&D efforts. The growth in production of food grains, fruits and vegetables, milk, eggs and fish has a few parallels at the global level. Potato is a singular case where the growth and development have been extremely encouraging. Averaged over last three years (1998-99 to 2000-01), the country produced 23.63 million tonnes of potatoes from an area of 1.2963 million hectares with an average yield of 18.23 t/ha (Table-1). Major potato producing area (70.50 %)

**Table-1: Average area, production and yield of potato in major potato producing states of India (Triennial average for the period 1998-99 to 2000-2001).**

| State | Area ('000 ha) | Production ('000 tonnes) | Yield (t/ha) |
|---|---|---|---|
| Uttar Pradesh | 435.67 (33.61) | 9594.03 (40.60) | 22.02 |
| West Bengal | 310.97 (23.99) | 7281.67 (30.82) | 23.42 |
| Bihar | 167.33 (12.91) | 1606.13 (6.80) | 9.60 |
| Punjab | 71.30 (5.50) | 1424.57 (6.03) | 19.98 |
| Madhya Pradesh | 53.57 (4.13) | 711.07 (3.01) | 13.27 |
| Gujarat | 31.90 (2.46) | 705.90 (2.99) | 22.13 |
| Assam | 78.07 (6.02) | 662.70 (2.80) | 8.49 |
| Karnataka | 34.97 (2.70) | 465.57 (1.97) | 13.31 |
| Haryana | 16.80 (1.30) | 264.57 (1.12) | 15.75 |
| Meghalaya | 19.70 (1.52) | 175.30 (0.74) | 8.90 |
| Himachal Pradesh | 12.10 (0.93) | 145.33 (0.61) | 12.01 |
| Orissa | 8.37 (0.65) | 87.77 (0.37) | 10.49 |
| Maharashtra | 15.73 (1.21) | 72.33 (0.31) | 4.60 |
| Others | 39.77 (3.07) | 423.47 (1.79) | 10.65 |
| All India | 1296.30 (100.00) | 23629.4 (100.00) | 18.23 |

Figures in parentheses indicate % of total area and production as the case may be.
(Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, New Delhi.)

in the country is located in three states namely Bihar, Uttar Pradesh, and West Bengal. The other important states Assam, Gujarat, Karnataka, Madhya Pradesh, and Punjab account for another 20.8% of area under potato in the country. Bihar, Uttar Pradesh and West Bengal, contribute 78.2% of total potato production in the country. Assam, Gujarat, Karnataka, Madhya Pradesh and Punjab together contribute another 16.8 % of total production. Though the country's average yield is 18.23 t/ha, the average yields among different states range from 4.60 to 23.42 t/ha. The states that have more than 20 t/ha yield are Gujarat, Uttar Pradesh, and West Bengal.

Since most of the potato production in the country is in north Indian plains and hills, the movement of potatoes from these regions is of special importance for ensuring availability of potatoes for most part of the year in the country (Table-2). The early crop in the plains is lifted in immature state during October/November, and is moved immediately to the consuming centres to take advantage of higher prices. A part of the main crop, which is harvested after maturity during February/March, is moved in the market immediately and remaining produce is stored in country or cold stores to meet the requirements of the consumers in the later part of the year. In some areas a late crop is taken in the spring, and is harvested at a time (April/May) when the temperatures in the plains of India start rising. The produce of this crop has a poor keeping quality. Therefore, it is disposed off immediately. This is followed by the immature produce from the mid-hills (July/August) and is supplemented with the supplies from the cold stores. This continues till potatoes from the high hills become available in the months of September-October.

**Table-2: Periods and sources of potato arrival in Indian markets**

| Period | Arrival of potatoes from | Quantity |
|---|---|---|
| January-May | Early and main crops of Uttar Pradesh, Bihar, West Bengal, Punjab, Madhya Pradesh, Assam, Haryana, and *Rabi* crop of Maharashtra, Orissa, and Gujarat. | High |
| May-June | Spring crops of north hills and north-western plains | Low |
| July-August | Summer crop of south Indian hills | Low |
| September-October | Summer crop of north hills and *Kharif* crop of plateau region | Low |
| October-December | Autumn crop of mid/low hills, and early crop of Punjab | Low |
| December-January | Autumn crop of south Indian hills | Low |

## PRODUCTION

The impact of extensive potato research and development in the country during last five decades had been phenomenal in all aspects of potato production. The crop has witnessed 5.2-fold increase in area, 13.3 % increase in production and 2.6 % increase in productivity in India during the period 1949-50 to 2000-2001. Averaged over last three years (1998-99 to 2000-01), the country produced 23.63 million tonnes of potatoes from an area of 1.30 million hectares with an average yield of 18.23 t/ha. Based on last five years (1997-2001) averages, globally India ranks 4th in area and 3rd in production. Although the productivity per unit area in India (17.84 t/ha) is little better than world average (15.88 t/ha), it is much lower than many countries of the Europe and America. Potato crop in these temperate countries is grown under long days and long growing season of 160-180 days. In contrast, more than 90 percent of the crop in India is grown in sub-tropical plains under short days and short growing season of 90 days. If potato productivity is expressed in terms of per unit area and time, India is likely to rank 1st for potato productivity in the world.

## VEGETABLE MIND SET TO SHIFT TO FOOD MIND SET

In developed countries potato is consumed as fresh staple food and processed products; industrial use for starch and alcohol production; and livestock feed. In developing countries, however, it is still primarily used as a vegetable. In India about 73% potatoes are consumed fresh in the form of vegetable, 10% as seed, less than 1% is processed, and another less than 1% is exported. A huge amount, approximately, 16% goes as waste. Although per capita potato availability in India is about 23 kg, its consumption (15 kg/year) is much less than other parts of the world (136 kg/year in Poland) and there is ample room for increasing consumption. To improve per capita consumption of potatoes, a publicity campaign can be launched through mass media such as television, radio and newspapers highlighting its nutritional value. Such awareness campaigns are already being done for eggs and milk. Most importantly there is a need to consider potato as a food crop rather than vegetable.

## EFFICIENCY, EFFECTIVENESS AND RELEVANCE IN PRODUCTION, PROCESSING, VALUE ADDITION, STORAGE, MARKETING AND TRADE

### Efficiency in energy conversion

Due to high protein-calorie ratio (17g protein: 1000 kcal) and short vegetative cycle, potatoes yield substantially more edible energy, protein and dry matter per unit area and time than many other crops. Potato allows farmers to harvest up to 80 percent of dry matter as edible, nutritious food. Only 50 percent of a cereal crop can be harvested as grain. This difference accounts for the high potential yield of potato. Crop physiologists estimate the potential yield of potato at about 120 tonnes per hectare or 30 tonnes per hectare grain equivalent, nearly twice that of cereals.

### Processing and value addition

Location of primary potato production being far away from the consuming centers necessitates its transportation over long distances. Lack of proper modes of transport, inadequate storage capacity and low per capita consumption results in 'gluts' soon after peak harvest in north Indian plains. Therefore, diversion of a part of the produce for processing, industrial use and export is expected to resolve most of the post harvest handling and marketing problems associated with this semi-perishable crop.

In developed countries, over the years, and especially since 50s, the percentage of the potato crop used for processing especially for producing French fries has steadily increased. The growth of the fast-food industry since 1960 is the main impetus behind the shift toward use of frozen French fries. In the year 2000-2001 export of frozen potato French fries from three major exporting countries, viz. USA, the Netherlands and Canada, are forecast at a record 2.3 million tonnes. U.S. frozen potato fry exports valued $ 338.315 million in 1999-2000, almost double in value and volume than just six years ago revealing an upward international trend of demand for frozen fries.

In India, home-scale processing of potato to produce chips, *papads*, dehydrated cubes, shreds etc. is common in all potato growing areas. However, there was no visible progress in potato processing under organized sector in the country until 1990. During the last decade growth of organized potato processing became apparent due to the incentives given by the Government. At present there are about 10 processing plants that produce potato chips and fries in the country. The growth rate of potato chipping in organized sector was 8% in 1990, 15% in 1992, 18% in 1994 but (-) 8% in 1998. Although overall growth rate during the decade had been 12 %, the recent decline in 1998 indicates that perhaps Indian industries are also downsizing chip production and shifting towards French fries or much needs to be done to foster this industry.

## Storage

Potatoes cannot be stored under ordinary conditions particularly in sub-tropical plains where high temperatures and dry weather prevails soon after its harvest. Therefore, to sustain increased potato production, proper storage facilities are essential. Earlier, some non-refrigerated storage structures were developed which included sandpits, diffused light storage rooms, thatched mud wall rooms, etc. These structures are suitable to hold potatoes upto 3-4 months. Obviously these structures cannot be used for storage of table, processing and seed potatoes for a longer period of 8-10 months. The cold storage of potato, therefore, is most appropriate technique for holding potato tubers for longer periods. The growth of cold storage industry has given a big boost to potato cultivation in India by facilitating availability of potato seed tubers in right physiological stage for planting and also ensured freedom from some diseases and pests that do not survive at low temperatures. However, with the progressive increase in production, the present cold storage capacity (10.55 million t in 1998) is not adequate. In most of the states 90% of the total capacity is used for cold storing potatoes, but in the states of Haryana and M.P. only 70% of total capacity is used for potato storage. Most of the cold stores are located near big towns and markets, and are unevenly distributed in different parts of the country and as such many of the growers do not have access to cold stores even now. Haryana, Punjab, Maharashtra, and Bihar exemplify this uneven distribution of cold stores in the country. Haryana and Punjab are nearly self sufficient for cold storing potato produce in the state, while Maharashtra is having excess cold storage facilities, but Bihar hardly has cold-store capacity for 22.4 per cent of total potato production in the state. With available total cold-storage capacity of 10.55 million t, only about 37.5 percent of total production can be cold-stored in the country.

Storage of table and processing potatoes at 3-4$^0$C in cold stores accumulate reducing sugars and hence such tubers are not fit for processing. Therefore, concerted efforts are needed create additional facilities for storing such potatoes at 10-12$^0$C at which sugar accumulation is reduced. After achieving this, available cold-storage capacity in the country can comfortably be used for storing seed potatoes.

### Marketing

The issues surrounding marketing of potato are quite complex, primarily because potato is a semi-perishable and bulky commodity with high water content. Therefore, it requires well-knit infrastructure of appropriate storage and transport throughout the country.

Most of the potato trade in India is done through commission agents or local shopkeepers. In some areas, trading of potatoes through co-operatives has also been initiated. The Government or the local bodies have very little or no control over the business or the trading methods, resulting in several deficiencies and malpractices in the business. Some of these could be overcome by establishing regulated markets under the Agricultural Produce and Marketing Act. The Act provides for proper grading and marketing of the produce as per the rules laid down for 'Agmark' grades.

Wholesale and retail prices of potato show seasonal variations during the year and from year to year depending upon the supply and demand. Generally, the prices are high at the beginning of the harvest and decline gradually as the supplies increase. Cold storage of potatoes during surplus months has helped moderate the price fluctuations in the country, though has not fully eliminated them. Market intelligence coupled with quick movement of potatoes from surplus to deficient areas would further moderate the prices.

### Diversified usage

Potato is a staple food in Europe and North America and almost a vegetable in the developing world including India. The diversified uses of potato cover fresh food, processed products, animal feed, seed and raw material for industries (mainly starch).

In India about 73% potatoes are consumed as fresh food in the form of vegetable, 10% as seed, less than 1% is processed, another less than 1% is exported and about 16% goes as waste. Per capita consumption of potatoes in India (15 kg/year) is much less than other parts of the world (136 kg/year in Poland) and there is ample room for increasing consumption. In India potatoes are also not used as animal feed or as industrial raw material for production of starch and alcohol. On processing front, as compared to the USA (60%), the Netherlands (47%) and china (22%), less than 1% of total potato production in the country is processed. In recent years the demand for processed potato products in the country as well as in international market has risen at a fast pace due to increased urbanization, rise in per capita income, increase in number of working women and expanding tourism.

## COMPETITION WITH CROPS, COMMODITIES, CROPPING SYSTEM, PRICE, QUALITY

In most parts of India, potato is an important constituent of intensive cropping systems either in rotation or as mixed crop.

Globally, about 8% of the increases in food production in the last half century have come from expansion of the cultivated area and 92% from higher yields per hectare. Considering these facts, one of the options left for increasing agricultural production is to improve the productivity per unit land and time. In this context potato has a great potential in modern agriculture for meeting the increasing food requirements in the world. Intensive cropping is another means by which productivity per unit land and time can be improved substantially without putting much pressure on scarce resources such as land, water, fertilizers etc. The concept of intensive cropping is more pertinent to tropical and sub-tropical countries where per capita availability of arable land is much less and the environmental conditions permit growth of more than one crop on same piece of land in a year. Short duration and wide flexibility in planting and harvesting time are potato's valuable traits that help in adjusting this crop in various intensive-cropping systems. The development of potato varieties with different maturity groups, which can be grown in different agro-climatic regions of the country, has further improved the acceptability of potato in intensive-cropping systems.

Wheat, rice, maize, sugarcane, jute, pulses, and vegetables are some of the major crops in the potato growing regions. Potato based cropping systems involving these crops have been developed and evaluated. Wheat can be grown in sequence or as inter-crop with potato. In sequence, timely sowing of wheat in spring can be ensured by using well-sprouted tubers of short duration potato variety for autumn potato crop and a late variety of wheat. However, due to heat stress, the yield of late wheat varies greatly over years depending upon weather conditions. Inter-cropping of wheat in between potato rows circumvents this problem to a greater extent. In this case wheat is sown in furrows after earthing-up of potato. Both in sequence, and as an inter-crop, phosphorous and potassium requirement of wheat is met by residues of these fertilizers left over by potato. The requirement of nitrogen is also reduced by about 50 percent. Potato-wheat inter-cropping can further be intensified by planting mung in paired rows in the space vacated by harvested potato. Potato can fit in two-rice crops or rice-jute system in northeastern plains. With sugarcane, potato can fit in sequence with spring sugarcane or as inter-crop with autumn or ratoon sugarcane. Short duration variety of potato should be preferred for inter-cropping with sugarcane. Inter-cropping involving crops like potato, onion, garlic, fennel; French bean etc. is also common.

It is a well-established fact that when potato is grown in crop rotations or as a mixed crop, the build-up of many insects and soil borne diseases is considerably reduced.

Thus, potato can play an important role in sustainable agriculture and food security without affecting production of other crops.

## Sustaining Advantages at Local, Regional and Global Level

In world food production, potato is exceeded only by maize, rice and wheat. Potatoes are consumed by over one billion people world over; half of them are in the developing countries.

Today potato is grown on about 19.3 million ha in 150 countries producing nearly 308 million tonnes. Increase in the share of developing countries in world potato area and production from 15.1 to 46.3 % and 10.5 to 44%, respectively, during 1961-2002 indicates its sustainability in developing economies and food security in these highly populated regions.

The developing countries are expanding potato production for several reasons. Firstly, potato crop produces more edible energy and protein per unit time and area compared to many other food crops. Secondly, for the small subsistence farmers, potato fits well into intensive cropping systems prevalent in tropical and sub-tropical agro-climatic conditions. Thirdly, the high profitability and employment generation during crop growth, transportation, marketing and processing gave a big boost to potato cultivation.

Rapid technological advances mainly improved varieties, agro-techniques, irrigation, processing, export etc. backed by government policies in developing countries can further stimulate expansion of potato production.

## SWOT ANALYSIS OF SCIENCE, TECHNOLOGY AND CAPABILITY

### Strengths

The main strength of the country lies in the extremely diverse agro-climatic conditions that support cultivation of potato in several parts of the country. The importance of potato has been recognized at the national level and we have one of the best research institutes engaged specifically on potato. Moreover, dedicated and trained scientific manpower, well knit research infrastructure, enterprising farming community, competitive industry and supportive government policies all favour development and spread of technologies that promote potato production.

Some of the important scientific achievements during last five decades are (i) development of 35 high yielding varieties, (ii) Seed Plot Technique, (iii) True Potato Seed (TPS) technology, (iv) development of region-wise packages of practices for ware and seed potato production, (v) identification of profitable potato based cropping systems, (vi) development of environment-friendly disease and pest management practices, and (vii) development of technologies for post harvest handling and value addition. These were major ingredients of potato revolution in India.

### Weaknesses

With increase in production, recurring gluts are common in the country. The prices crash drastically during months of plenty leading to panic sale by the farmers and incurring monetary losses. Lack of proper marketing avenues, insufficient/expensive cold storage facilities and low domestic utilization are some of the other problems. The fact is that our country is not yet prepared to absorb excess potato production. A suitable post harvest and processing industry is the need of the hour. It is high time that diversified utilization and export oriented research programmes are initiated to cope with increased potato production in the country. The great potential for exporting both seed and table potatoes and processed products has hardly been explored.

### Opportunities

A short duration crop like potato, which is nutritionally superior and capable of producing high amount of food per unit area and time, has a great potential in modern agriculture. In a country like India with large population to feed, potato is perhaps the one of the best answers to meet the growing food needs. According to the estimates published by the International

Food Policy Research Institute (IFPRI) and International Potato Center (CIP), India is likely to have highest growth rates in production and productivity of potatoes during 1993-2020. During the same period worldwide demand of potatoes is expected to increase by 40%. This scenario calls for concerted efforts to capture global market by producing international quality potatoes and processed products. Projections made by the Central Potato Research Institute (CPRI) also indicate production of 49 million tonne potatoes from an area of 2 million ha by the year 2020. Potato production and utilization pattern in the world including India is changing very fast. Recourse to application of biotechnological tools for introducing desirable quality traits, while addressing the concerns of biosafety, may be an imperative. The changes harbour many opportunities and challenges. If we want to be nationally comfortable and globally competitive, we have to keep pace and adapt to the new emerging trends in potato production and utilization.

## Threats

The threats to potato production emanate from wide range of biotic and abiotic stresses and excessive, often indiscriminate use of chemicals. The large quantities of pesticides and fertilizers have on several occasions affected the quality of the produce. Stresses on account of global climatic change, scarcity and quality of water, emergence of new pests and diseases would manifest directly or indirectly, proper counter measures need to be devised. These concerns should put development integrated management practices on use of fertilizers (IPNS) and disease/pest (IPM) as high priority research agenda.

The other major threat relates to marketing and trade. In WTO era there is fierce competition in the world market and the regulations are becoming stringent. If we want to be nationally comfortable and globally competitive in terms of quality and cost of produce, we have to keep pace and quickly adjust to the emerging trends in potato production scenario. An appropriate sanitary and phyto-sanitary (SPS) system needs to be put in place.

## Post Harvest Technology

Indian varieties suitable for processing are Kufri Chandramukhi, Kufri Jyoti, Kufri Lauvkar, Kufri Chipsona-1 and Kufri Chipsona-2. The former three varieties were bred primarily for high yields and fresh consumption; it is only a coincidence that in addition to high yields, they meet minimum requirements for processing. The other two varieties K. Chipsona-1 and K. Chipsona-2 possess 2-3% high dry matter and low reducing sugars and were specially bred for chip making.

There are no special varieties for producing French fries in India and in their absence the same set of varieties as above are also used for this purpose. Therefore, efforts are urgently needed to accelerate development of different types of varieties suitable for processing into different products and cultivation in varied agro-climates of the country.

This situation also calls for (i) development of processing varieties that do not accumulate reducing sugars and can be stored for longer periods at 10-12 $^0$C without sprout suppressant treatment and/or (ii) development of "Cold Chipper Varieties" accumulating less reducing sugars at 4-6$^0$C that can be used for processing after reconditioning at 15-18 $^0$C. Since at present we do not have such varieties, Chlorpropham (CIPC) treatment is the only alternative available to store processing potatoes at 10-12 $^0$C for longer periods.

Developmental needs for processing are given under issues, strategies, probable interventions and linkages.

## Critical Research Interventions and Linkages

The most critical aspect is diversified utilization of potatoes. This includes enhancing domestic consumption, processing and export. Ways and means are given below.

### Technologies

i) To make potato research more competitive, additional funds need to be allocated. It may be considered to increase the funds to 0.5% from only 0.16% of the total value output by potato.

ii) In our country the research is primarily driven by public investment. Private-public linkages need to be developed in India. Investment by private companies in research should be made mandatory.

iii) For strong exchange of information and scientific collaboration, a "Potato Network" in SAARC Countries would be an efficient medium for development of this crop in South Asian Countries.

iv) The Potato Development Council was set up in 1977 under the Ministry of Agriculture, Govt. of India to formulate new policies for potato development. However, this council was never re-constituted after the expiry of its first term. It is now proposed that a "Potato Board" be constituted at national level with a permanent Executive Director to take care of the interests of this important crop or a separate potato section under overall control of Director needs to be created in the National Horticultural Board (NHB).

v) The breeders' seed production programme, therefore, needs to be strengthened by involving State Agricultural Universities (SAUs). Revolving Fund Schemes for potato breeders' seed production can be given to SAUs to meet the national requirements.

vi) A strong national extension network involving CPRI, SAUs, and State Departments of Agriculture/Horticulture needs to be established for transfer of technology and collecting feed back from the farmers.

### Storage

i) While the cold storage remains the best option for storage of seed potatoes, it is not the solution for storing potatoes for table use and processing. Moreover, these stores require lot of energy and the storage is expensive. There is an urgent need for involving technically competent organizations to develop low-cost on-farm storage structures run on passive cooling/solar energy technologies and the marketing and processing centres be located close to the areas of production.

## Marketing

i) The major problems of the potato growers include recurrent price fluctuations and price crashes, high marketing, storage and transport costs, non-availability of adequate storage facilities, and lack of competitive marketing system. Need for a National Potato Marketing Board has been emphasized to take care of the above problems. To reduce the price gap between growers and consumers, there is a need for promoting producer's co-operatives.

ii) The National Agriculture Co-operative Marketing Federation Ltd. (NAFED) and Agricultural and Processed Food Products Export Development Authority (APEDA) have limited activities in potato marketing and export. There is an urgent need for expansion of potato marketing activities by NAFED and APEDA.

iii) Information and Communication Technologies (ICTs) systems should be set up to retrieve and analyze and provide quality information efficiently and quickly for the marketing and other services needs of the growers and co-operatives.

## Processing

i) One of the major constraints in the development of potato processing industry in developing countries is the lack of potato varieties suitable for processing. Although CPRI has recently released two processing varieties viz. Kufri Chipsona-1 and Kufri Chipsona-2 suitable for growing in northern plains of the country, there is a need to develop more such varieties for other regions.

ii) Potato processors in India have to import processing machinery at high custom duty. Addition of excise duty on processed products and high electricity tariff results in high product cost makes the products unattractive to the consumers. Rationalisation of custom duty, tax and tariff on electricity is necessary for making the processed products cost effective and competitive.

iii) Although reliable information on village level potato processing is not available, this needs to be streamlined through Small Scale Industries, Co-operatives, Village Panchayats, and NGOs. Variety of dehydrated potato products such as *Papads*, Potato Dice, Flakes, Chips, Potato Flour or Granules etc. can be produced in these small units for local consumption.

## Export

a. A serious effort should be made to conduct global survey and identify export markets for Indian potatoes and processed products. This can begin with the neighbouring SAARC and Gulf countries. Later it can be extended to other potential countries. A delegation consisting of representatives from different organizations may visit major importing countries viz. UAE, Mauritius, Singapore, Honking, Sri Lanka and Nepal and develop a clear idea about their preferences, market situation and competitors. Based on the information collected the Government should formulate a long-term export policy for potatoes.

b. After identifying potential markets, there should be some arrangement with some international agency to provide expert market intelligence.

c. An organized and sustained effort should be made to enter the seed potato market in SAARC countries and processed potato product market in the Gulf countries.

d. There should be strict and transparent quality enforcement system.

e. The government should assess the export potential every year and export targets should be announced every year before the planting season. The requirements from importing countries regarding the variety, shape, colour and texture of potatoes should also be ascertained and announced well in advance.

f. Areas suitable for growing potatoes of desirable quality have been identified. Making use of this information, export zones for table, seed, and processing grade potatoes should be identified in the country. This exercise may become a part of the identification of Agri-Export Zones being promoted by APEDA.

g. The Sri Lankan Government has imposed a surcharge of LKR 20 per kg on potatoes imported from India. The Govt. of India can get in touch with the Sri Lankan government and persuade them to lift the surcharge on potatoes from India and to give India the same level play ground as is being given to other countries.

h. There is a need to study oceanic freight system from India to Asian and Gulf countries so that vessel are available at reasonable rates for potato exporters from India. Presently the freight charges from Europe to Sri Lanka are cheaper than that from India to Sri Lanka.

**Epilogue:** In India the importance of potato and potato based food items in the national efforts to combat hunger and malnutrition will surely increase in times to come. Though we have attained a place among the leading producers of the crop at global level but still we have to address several issues of sustainable potato production viz. productivity and quality enhancements, building resistance to stresses, post harvest management, marketing and trade etc. The NARS efforts have to be suitably tuned to the emerging needs backed by favourable policy and financial back up. There is absolutely no doubt that the further developments will come only by application of new techniques and technologies that are going to be both, knowledge and resource intensive. Hence timely investments in agricultural research are essential to realize the cherished goal of national prosperity and slackness on this count now could prove much more costlier in the future.

# Gaps in potato research and adoption of improved technologies in India

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## About Dr Gautam Kalloo

Dr Gautam Kalloo, DDG (Hort.) an Eminent Scientist has developed a large number of varieties of vegetable crops, being widely grown throughout the country. He has been instrumental in the development of Indian Institute of Vegetable Research, Varanasi, a premier organization of vegetable research which is one of the best Institutes of international standard. The vegetable production has been doubled from 45 million tones to 90 million tones because of his research, policy planning and execution of research programmes in the country.

He has published more than 250 articles in various national and international journals, guided a number of M.Sc. and Ph.D. students. He has visited a number of countries to pursue the research on vegetable crops. and authored more than 10 books published form international publishers.

He has developed more than 42 varieties and hybrids in vegetable crops including disease resistant varieties especially resistance to TLCV, wilt and RKN in tomato, YVM and enation leaf curl virus in okra and powdery mildew in peas are notable.

He has won several awards including ICAR Team Award for outstanding contribution in the field of horticulture and Rafi Ahmad Kidwai Award (2001-2002), etc.

Potato was introduced by the European colonizers about 300 years ago and it emerged as a wonder crop in post-independent India. It was readily adopted as a food crop because of the people's familiarity with several other root and tuber crops. Moreover, the crop produces substantially more edible energy, protein and dry matter per unit area and time than many other crops. During the last four decades India recorded highest annual compound growth rates for potato production and yield, but, its per capita consumption in India has not increased much during the last 50 years. As a consequence, India is producing more potato than it can actually utilize, resulting in temporary gluts and price collapse. This trend in potato production seems to continue at least till 2020. During the same period the worldwide demand for potatoes is expected to increase by 40%. This scenario calls for immediate efforts to capture the global market by producing international quality fresh potatoes and value added/processed products. As both ware and seed potatoes produced in India have competitive advantage in respect to quality and price over those from many other exporting countries. The growing period during winter months also contributes a major advantage for export of Indian potatoes to European market.

Central Potato Research Institute has played a key role in popularizing potato in India. The institute has emerged not only as a leader in the area of crop research in India but internationally as a leader of potato research in the subtropics. However, in this era of globalization and highly competitive market economy, there is no place for complacency. It is necessary to clearly identify our research gaps and weaknesses. Potato has potentiality of a major export commodity provided appropriate policy and infrastructure supports are taken care of. The research and development priorities should also be reoriented keeping in view the emerging export opportunities.

Major thrust should now be given on development of varieties with internationally accepted quality standards and better processing attributes. Conventional breeding should be supplemented appropriately with modern biotechnological tools to achieve that objective. It is necessary to generate data on all necessary morphological descriptors of the Indian potato cultivars as per UPOV guidelines. DNA fingerprints of all our parental lines, promising hybrids and cultivars should be prepared. It is an urgent necessity to evolve agronomical methods for efficient management of soil, nutrients, water, and space. Suitable management practices should be devised for bioremediation of degraded soil. Minimum standards for export of ware and seed potatoes should be updated in tune with international protocols. Pest risk analysis of potato may be got done on priority. A database of potato disease/pest situation in India and its neighboring countries should be developed. Computer based expert systems for identification and management of potato diseases and pests already prepared by the institute may be further refined and popularized. Diagnostic tools for detection of ultra low inoculum level in tubers and other plant materials should be developed for different fungal, bacterial and viral pathogens. Diversification in end product utilization and processing of potatoes to produce industrial raw materials like starch, alcohol, animal feed etc. may be explored on priority. The ideal storage temperature for table and processing quality potatoes is 10-12°C and Chloro Isopropyl Phenyl Carbamate (CIPC) is used to suppress sprouting at this temperature. The food safety issue of CIPC in stored potato is still debated in developed countries. Therefore, the permissible limit of CIPC in tubers should be worked out and health aspects in collaboration with institutes like NIN, Hyderabad. It is also necessary to generate extensive data on nutritive value of potato tubers before and after storage at 10-12°C with CIPC treatment and identify alternate organic equivalents of CIPC. The breeders' seed production programme needs to be strengthened by involving private organized sector. The State Department of Agriculture/Horticulture should develop strong linkages with NGO's, Village Panchayats, Farmers' Cooperative, and Progressive farmers for effective utilization of Breeder's seeds. Constitution of farmers' cooperative in seed producing belt can be initiated by State administration by encouraging the farmers. Revolving fund schemes for the State agriculture farms, NGOs, village Panchayats and farmers' cooperatives for large-scale production of certified seed potato. Thus, sincere efforts are required to make the farmers aware about the importance of adopting package of practices developed for potato by the CPRI.

# CPRI: five decades of potato research and development

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With present population growth rate, India is likely to be the most populous country of the world by 2055. Poverty and large population are significant and persistent problems in India. These problems besides having close relationship with food insecurity are also related to poor health and loss of human potential. Food security in India is, therefore, an important national priority. Potato, a short duration crop that produces more dry matter, edible energy and protein per unit land and time than many other major crops such as wheat, rice and maize, is the most potential and nutritionally superior crop for fighting hunger and malnutrition. Short duration and wide flexibility in planting and harvesting time are potato's valuable traits that help adjusting this crop in various intensive-cropping systems without putting much pressure on scarce resources such as land, water, fertilizers etc. It also generates larger returns per unit land and time.

## POTATO RESEARCH

**Central Potato Research Institute, Shimla**

Potato research and development in India can be divided into two phases. In the first phase prior to independence, the erstwhile Provincial Governments initiated potato research and development in India as early as in the first quarter of 19th century. The research and development efforts by these governments continued until potato research was organized at national level by establishment of **Central Potato Research Institute (CPRI) in 1949.** This was the beginning of second phase of potato research and development in the country. With expansion of national network of potato research, the localized research activities in the states tapered off and at present most of the potato research is carried out at the national level through the Central Potato Research Institute and All India Coordinated Research Project on Potato (AICRP, Potato).

### Need for Indigenous Potato Research

Potato is not native to India and it was introduced in India from Europe in the beginning of early 17th century. The early introductions were closely related to *Solanum tuberosum* ssp. *andigena*. During 1824 to 1939 systematic attempts were made to introduce new potato varieties in the country, mainly from Europe. These, however, could create very little impression as most of these varieties either failed to yield well under Indian conditions or degenerated and were lost. The failure of introduced varieties in India was mainly because these varieties were primarily bred to suit temperate long days of summer in Europe, whereas, potato in India is grown during short days of sub-tropical winters. Contrasting potato cultivation features in Europe and India are given in Table 1.

**Table 1. Agro-climatic peculiarities of growing potatoes in sub-tropics**

| Agro-climatic parameters | Sub-tropical countries | Temperate countries |
|---|---|---|
| Growing season | Winter | Summer |
| Temperatures during planting and harvesting | High (Planting: 25-30 ºC; Harvesting:10-20 ºC) | Low (15-25 ºC at both) |
| Crop duration | 90-100 days | 150-180 days |
| Photoperiod during growth | 10.3 hrs/day | 14 hrs/day |
| Day/night temperatures | 25-30 ºC / 04-15 ºC | 25 ºC / 15 ºC |
| Frosting | Common | Absent |
| Temperatures immediately after harvest | Very high (Harvest is followed by summer) | Very low (Harvest is followed by winter) |

A need was, therefore, felt that potato cultivation in India can not depend on exotic varieties and technologies and the country must have its own research and development program for potato. A scheme for establishment of Central Potato Research Institute was, therefore, drawn up in 1945 under the guidance of Sir Herbort Stewart, the then Agricultural Advisor to the Government of India and CPRI was established in 1949 at Patna. Hills being the ideal location for producing and maintaining healthy seed and using wide potato genetic base through hybridization for breeding improved varieties, on the recommendations of an expert committee, the headquarters of CPRI was shifted in hills at Shimla in 1956.

During the period 1956 to 1983, a chain of regional research stations was established in different potato growing zones of the country to address local problems of potato cultivation. At present the institute has seven regional research stations located at Kufri (Himachal Pradesh), Jalandhar (Punjab), Patna (Bihar), Shillong (Meghalaya), Modipuram (Uttar Pradesh), Gwalior (Madhya Pradesh) and Ootacamund (Tamil Nadu). While research stations located at Darjeeling (West Bengal), Mukteshwar (Uttaranchal) and Rajgurunagar (Maharashtra) were closed some time back. The Indian Council of Agricultural Research (ICAR) started AICRP on potato in 1971 with its headquarters at CPRI, Shimla. At present this AICRP has 22 centers located at several State Agricultural Universities and the regional stations of CPRI. Improved varieties of potato and potato related agro-techniques developed in the country are evaluated in these centers before they are recommended for commercial use. Together, the CPRI and AICRP account for more than 95% potato related research in this country. As a result of organized potato research on developing indigenous varieties and agro-techniques, the increase in area, production and yield of potato during last 50 years has been almost phenomenal. The following are some of the major achievements during post independence era.

- Use of GIS for spatial and temporal diversification. Cursory look at the meteorological and soil data indicates that potato cultivation is possible in many additional locations other than Indo-Gangetic plains. Using GIS, these places have been identified for spatial diversification. Temporal diversification is possible through increase in the area and productivity of early and spring crops in the northern Indo-Gangetic plains. This is expected to spread the availability of fresh potato for a long period and reduce the gluts.

- Simulation modelling is another useful tool for helping to work out tactical decisions. Potato models have been developed to determine the best growing period, yield potential during the growing period, the optimum management practices to achieve the yield potential and also develop new efficient cropping systems.

- There is much scope for use of remote sensing in potato development. The tool is being used for estimation of acreage and production prior to harvest so that proper planning can be made in advance for marketing, storage etc.

- An expert problem solving behaviour of computer aided Expert Systems can be advantageously utilized for economic planning and management of different crops. Potato expert system for management of nutrients, insect pests and diseases has been developed at CPRI.

- In addition to late blight resistant cultivars, late blight forecasting systems were developed for the hills and plains to manage this dreaded disease. These have been instrumental in reducing the labour and cost on plant protection by avoiding unnecessary and untimely use of fungicides.

- In order to make potato cultivation eco-friendly, integrated packages of practices for management of late blight, bacterial wilt, viruses and soil & tuber-borne diseases, potato tuber moth (PTM) and cyst nematodes were developed. These packages included host resistance, sanitation, crop rotations, use of safer chemicals, predators, bio-control agents, botanicals and agronomic practices.

- Developed sensitive virus detection methods such as ELISA, ISEM and NASH. Such sensitive methods have been of great help in eliminating quarantine material having low concentration of viruses/viroids and also testing of mericlones. Besides, deployment of these methods in seed production was responsible for practically zeroing the virus incidence in basic/nucleus seed.

- Standardized tissue cultural techniques for micropropagation, *in vitro* conservation of genetic

**A View of Tissue Culture Lab at Shimla**

resources and genetic transformation. Meristem culture coupled with micropropagation has been successfully integrated with potato seed production programme. More than 1300 germplasm accessions have been conserved in *in vitro* form and we plan to conserve entire germplasm within next 10 years. An efficient method has also been developed for long term cryoconservation in potato. Potato transgenics have been developed for insect resistance (*cry1Ab* gene), virus resistance (*CP-PVY* gene) and superior nutritional quality (*AmA1* gene producing essential amino acid rich storage protein). Field-testing of *AmA1* transgenics is in advanced stage, while other transgenics are awaiting permission from the Department of Biotechnology, Govt. of India for conducting limited field-testing.

- Molecular characterization of 35 commercial cultivars and 24 advanced hybrids has been done using RAPD and SSRs.
- The scientists at CPRI have also cloned *osmotin* and *invertase inhibitor* genes from *Solanum chacoense*. It is envisaged to deploy these genes for management of drought/ late blight and cold induced sweetening in potato, respectively.
- Improvised low cost on-farm storage structures that can hold table/processing potatoes for 3-4 months were developed for north Indian plains.
- Storage of table and processing potatoes at 3-4 $^0$C in cold stores accumulate reducing sugars and such tubers are not fit for processing. Therefore, efforts are being made for storing such potatoes at 10-12 $^0$C at which sugar accumulation is reduced. Prior to such storage, the tubers need to be treated with CIPC to prevent sprouting during storage. Studies are being conducted at CPRI to replace CIPC treatment with other safer alternatives mainly botanicals.
- Dissemination of technologies developed above is one of the major activities of CPRI. This has been achieved through technical/extension bulletins, training courses and several other programmes like Lab-to-Land, ORP, TAD, IVLP and TAR.
- To pool resources and expertise in the country, several research and development linkages have been developed by CPRI. Some of these are with CIP, Lima, Peru; NRCPB, IARI, New Delhi; NCPGR, New Delhi; TERI, New Delhi; BARC, Trombay; NDDB, New Delhi; HP University, Shimla and HPKVV, Palampur, and some private sector companies.

## POTATO DEVELOPMENT

The Department of Agriculture and Cooperation, Ministry of Agriculture; Department of Agricultural Research and Education (DARE), Government of India; and Indian Council of Agricultural Research (ICAR) with a chain of their offices are mainly responsible for potato development in the country. Besides, public sector undertakings, state departments of agriculture/horticulture, and non-government organizations also play an important role. Some of the important organizations involved in potato development at national level are given below.

**National Horticulture Board (NHB):** Under the Ministry of Agriculture, Government of India, the National Horticulture Board reviews the progress of research and development in horticultural crops including potato and recommends new guidelines from time to time.

**Central Sub-Committee for Crop Standards and Variety Release:** The sub-committee set up in 1966 is responsible for notification of crop varieties in the country. It also fixes seed standards of breeders', foundation and certified seed for different crops.

**Central Potato Seed Distribution Committee:** This committee was set up in 1966 and is responsible for monitoring potato seed production program and distribution of potato breeder's seed among State Departments of Agriculture/Horticulture, National Seed Corporation, and other seed producing agencies.

**National Seed Project (NSP):** In 1975, ICAR sanctioned a National Seed Project with the assistance of the World Bank to support seed production including seed certification and marketing in the country. This program assists the states in establishing seed certification agencies, marketing boards and in strengthening seed production program.

**Ministry of Food Processing Industries, Govt. of India:** This ministry was of recent origin and worked only for few years. It was responsible for identification of constraints faced by food processing industries, providing government support to promote and foster them, assessment of global demand, identification of new enterprises, and policy planning. Potato processing was one of the agenda of this ministry.

**Central Potato Research Institute:** Production of potato breeders' seed in the country is one of the major responsibilities of CPRI. The Institute organizes regular training courses on potato production technology and on seed production and certification for field functionaries involved in potato programmes in various State Departments and Agricultural Universities. The institute also organizes International Training Courses on potato in collaboration with the International Potato Center (CIP) in which potato workers of South and West Asian Countries are trained. It has a strong transfer of technology program at headquarters as well as at its regional stations for the benefit of farmers.

**Agricultural and Processed Food Products Export Development Authority (APEDA):** This is an important organization of the Govt. of India, which provides funding for promoting export of agricultural and processed food products including potato.

**National Agricultural Cooperative Marketing Federation Ltd.(NAFED):** This organization promotes potato marketing, both within the country and abroad. It is also involved in procurement of onions and potatoes under Market Intervention Scheme (MIS) of the government.

**Directorate of Plant Protection, Quarantine and Storage:** The Directorate is responsible for all aspects of plant health including monitoring the relative importance of diseases and pests. It also imposes quarantine regulations to prevent introduction of exotic diseases and pests from foreign countries and also for preventing spread of diseases from one region to another within the country. This Directorate put two potato producing areas in the country viz. Sikkim and north Bengal hills (infested with wart), and south Indian hills (infested with cyst nematodes) under quarantine regulations.

**Indian Potato Association (IPA):** The Association was founded in 1974 at CPRI, Shimla with the objectives to advance the cause of potato research; provide opportunity for interaction between planners, scientists, development and extension workers, and farmers by organizing periodical conferences, symposia, seminars, and workshops. It publishes a potato research journal and a potato newsletter.

## IMPACT OF POTATO RESEARCH AND DEVELOPMENT

The impact of extensive potato research and development in the country during last five decades had been phenomenal in all aspects of potato production. The crop has witnessed 516% increase in area, 1334 % increase in production and 257 % increase in productivity in India during the period 1949-50 to 2000-2001 (Table 2). Averaged over last three years (1998-99 to 2000-01), the country produced 23.63 million tonnes of potatoes from an area of 1.2963 million hectares with an average yield of 18.23 t/ha (Table 3). Based on last five years (1997-2001) averages, globally India ranks 4th in area, 3rd in production and 10th in productivity (Table 4). Although the productivity per unit area in India is little better than world average (15.88 t/ha), it is much lower than many countries of the Europe and America. Potato crop in these temperate countries is grown under long days and long growing season of 160-180 days. In contrast, more than 90 percent of the crop in India is grown in sub-tropical plains under

**Table 2. Increase in area, production and productivity of potato from 1949-50 to 2000-2001 in India**

| Period | Average area (million ha) | Average production (million tonnes) | Average productivity (t/ha) |
|---|---|---|---|
| 1949-50 to 1953-54 | 0.249 | 1.772 | 7.15 |
| 1954-55 to 1958-59 | 0.300 | 1.938 | 6.50 |
| 1959-60 to 1963-64 | 0.305 | 2.772 | 7.18 |
| 1964-65 to 1968-69 | 0.480 | 4.034 | 8.38 |
| 1969-70 to 1973-74 | 0.504 | 4.572 | 9.09 |
| 1974-75 to 1978-79 | 0.662 | 7.796 | 11.74 |
| 1979-80 to 1983-84 | 0.742 | 10.004 | 13.45 |
| 1984-85 to 1988-89 | 0.868 | 12.928 | 14.86 |
| 1989-90 to 1993-94 | 1.002 | 15.798 | 15.79 |
| 1994-95 to 1998-99 | 1.192 | 20.344 | 17.03 |
| 1999-00 to 2000-01 | 1.284 | 23.638 | 18.40 |
| % Increase during 1949-50 to 2000-2001 | 516 | 1334 | 257 |

(Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, New Delhi) short days and short growing season of 90 days. If potato productivity is expressed in terms of per unit area and time, India is likely to rank 1st for potato productivity in the world.

## SHORTFALLS

With increase in potato production, recurring gluts are common in the country. The prices crash drastically during months of plenty leading to panic sale by the farmers and incurring monetary losses. Lack of proper marketing avenues, insufficient/expensive cold storage facilities and low domestic utilization are some of the other problems. The great potential for exporting seed, table potatoes and processed products has hardly been explored. In the true sense our country is not yet prepared to absorb excess potato production. The issues that need urgent attention of the planners are development of policies for promoting utilization, storage, marketing, processing and export. Contract/co-operative farming to achieve scale of production, promotion of processing both at cottage and organized sector levels, development of export infrastructure and reorientation of exim policies including export subsidies are some of the important issues that need to be addressed on priority.

**Table 3. Average area, production and yield of potato in major potato producing states of India (Triennial average for 1998-99 to 2000-2001)**

| State | Area ('000 ha) | Production ('000 tonnes) | Yield (t/ha) |
|---|---|---|---|
| Uttar Pradesh | 435.67 (33.61)* | 9594.03 (40.60)* | 22.02 |
| West Bengal | 310.97 (23.99) | 7281.67 (30.82) | 23.42 |
| Bihar | 167.33 (12.91) | 1606.13 (6.80) | 9.60 |
| Punjab | 71.30 (5.50) | 1424.57 (6.03) | 19.98 |
| Madhya Pradesh | 53.57 (4.13) | 711.07 (3.01) | 13.27 |
| Gujarat | 31.90 (2.46) | 705.90 (2.99) | 22.13 |
| Assam | 78.07 (6.02) | 662.70 (2.80) | 8.49 |
| Karnataka | 34.97 (2.70) | 465.57 (1.97) | 13.31 |
| Haryana | 16.80 (1.30) | 264.57 (1.12) | 15.75 |
| Meghalaya | 19.70 (1.52) | 175.30 (0.74) | 8.90 |
| Himachal Pradesh | 12.10 (0.93) | 145.33 (0.61) | 12.01 |
| Orissa | 8.37 (0.65) | 87.77 (0.37) | 10.49 |
| Maharashtra | 15.73 (1.21) | 72.33 (0.31) | 4.60 |
| Others | 39.77 (3.07) | 423.47 (1.79) | 10.65 |
| All India | 1296.30 (100.00) | 23629.4 (100.00) | 18.23 |

* Figures in parentheses indicate % of total area and production as the case may be.

(Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India, New Delhi.)

## Utilization

In India about 73% potatoes are consumed as fresh food in the form of vegetable, 10% as seed, less than 1% is processed, another less than 1% is exported and about 16% goes as waste. Although per capita potato availability in India is about 24 kg, its consumption (16 kg/year) is much less than other parts of the world (136 kg/year in Poland) and there is ample room for increasing consumption. In India potatoes are neither used as animal feed nor as industrial raw material for production of starch and alcohol. On processing front, as compared to the USA (60%), the Netherlands (47%) and China (22%), less than 1% of total potato production in the country is processed. In recent years the demand for processed potato products in India and international market has risen at a fast pace due to increased urbanization, rise in per capita income, increase in number of working women and expanding tourism.

**Table 4. Average area, yield and production in 15 major potato producing countries of the world (Five-year average 1997-2001)**

| Country | Area (million ha) | Yield (t/ha) | Production (million t) | Rank[b] | | |
|---|---|---|---|---|---|---|
| | | | | A | Y | P |
| Belarus | 0.6898 | 11.44 | 7.88 (2.58) [a] | 6 | 13 | 8 |
| Canada | 0.1562 | 28.04 | 4.38(1.43) | 14 | 7 | 13 |
| China | 4.2467 | 14.24 | 60.22 (19.70) | 1 | 12 | 1 |
| France | 0.1671 | 38.99 | 6.52 (2.13) | 12 | 5 | 11 |
| Germany | 0.2987 | 40.19 | 12.01(3.93) | 8 | 3 | 7 |
| India | 1.2915 | 17.84 | 23.09 (7.55) | 4 | 10 | 3 |
| Islamic Rep. of Iran | 0.1600 | 20.98 | 3.36 (1.10) | 13 | 9 | 14 |
| Japan | 0.0989 | 30.77 | 3.05 ((1.00) | 15 | 6 | 15 |
| Netherlands | 0.1816 | 41.61 | 7.56 (2.47) | 10 | 1 | 9 |
| Poland | 1.2628 | 17.62 | 22.26 (7.28) | 5 | 11 | 4 |
| Russian Federation | 3.2721 | 10.28 | 33.66 (11.01) | 2 | 14 | 2 |
| Turkey | 0.2098 | 25.59 | 5.37 (1.76) | 9 | 8 | 12 |
| Ukraine | 1.5735 | 9.92 | 15.63 (5.11) | 3 | 15 | 6 |
| United Kingdom | 0.1685 | 40.31 | 6.79 (2.22) | 11 | 2 | 10 |
| USA | 0.5380 | 40.04 | 21.54 (7.04) | 7 | 4 | 5 |
| World | 19.2494 | 15.88 | 305.76 (100) | - | - | - |

[a] Figures in parentheses indicate percentage of world production
[b] World rank for area (A), yield (Y) and production (P).
(Source: FAOSTAT Database)

## Storage

Potatoes can not be stored under ordinary conditions particularly in sub-tropical plains where high temperatures and dry weather prevails soon after its harvest. Therefore, to sustain increased potato production, proper storage facilities are essential. Earlier, some non-refrigerated storage structures were developed which included sandpits, diffused light storage rooms, thatched mud wall rooms, etc. These structures are suitable to hold potatoes upto 3-4 months. Obviously these structures can not be used for storage of table, processing and seed potatoes for a longer period of 8-10 months. The cold storage of potato, therefore, is most appropriate technique for holding potato tubers for longer periods. The growth of cold storage industry has given a big boost to potato cultivation in India by facilitating availability of potato seed tubers in right physiological stage for planting and also ensured freedom from some diseases and pests that do not survive at low temperatures. However, with the progressive increase in production, the present cold storage capacity (10.55 million t in 1998) is not adequate. In most of the states 90% of the total capacity is used for cold storing potatoes. Most of the cold stores are located near big towns and markets, and are unevenly distributed in different parts of the country and as such many of the growers do not have access to cold stores even now. Haryana, Punjab, Maharashtra, and Bihar exemplify this uneven distribution of cold stores in the country. Haryana and Punjab are nearly self sufficient for cold storing potato produce in the state, while Maharashtra is having excess cold storage facilities, but Bihar hardly has cold-store capacity for 22.4 per cent of total potato production in the state. With available total cold-storage capacity of 10.55 million t, only about 37.5 percent of total production can be cold-stored in the country.

Storage of table and processing potatoes at 3-4$^0$C in cold stores accumulate reducing sugars and hence such tubers are not fit for processing. Therefore, concerted efforts are needed to create facilities for storing potatoes at 10-12$^0$C at which sugar accumulation is reduced. After achieving this, available cold-storage capacity in the country can comfortably be used for storing seed potatoes. But at this temperature potato tubers need to be treated with sprout suppressants like CIPC (chlorpropham). Here a word of caution needs to be added that being a herbicide, use of CIPC is now under scrutiny in many countries. Under such conditions there exist two possibilities, (i) to develop processing varieties that do not accumulate reducing sugars and can be stored for longer periods at 10-12$^0$C without sprout suppressant treatment, and (ii) to develop "Cold Chipper Varieties" accumulating less reducing sugars at low temperatures that can be used for processing after a short period of reconditioning at 15-18$^0$C.

## Marketing

The problems of potato marketing are not as simple as many other field crops. Potato is a semi-perishable and bulky commodity with high water content. Therefore, it requires a suitable and well-knit infrastructure for appropriate storage and transport throughout the country.

Most of the potato trade in India is done through commission agents or local shopkeepers. In some areas, trading of potatoes through co-operatives has also been initiated. The Government or the local bodies have very little or no control over the business or the trading methods, resulting in several deficiencies and malpractices in the business. Some of these could be overcome by establishing regulated markets under the Agricultural Produce and Marketing

Act. The Act provides for proper grading and marketing of the produce as per the rules laid down for 'Agmark' grades.

Wholesale and retail prices of potato vary from time to time, during the year and from year to year depending upon the supply and demand. Generally, the prices are high at the beginning of the harvest and decline gradually as the supplies increase. Cold storage of potatoes during surplus months has helped moderate the price fluctuations in the country, though has not fully eliminated them. Market intelligence coupled with quick movement of potatoes from surplus to deficient areas would further moderate the prices.

## Processing

Location of primary potato production centers far away from the consuming centers necessitates transportation of potatoes over long distances. Lack of proper modes of transport, inadequate storage capacity and low per capita consumption results in 'gluts' soon after peak harvest in north Indian plains. Therefore, diversion of a part of the produce for processing, industrial use and export is expected to resolve most of the post harvest handling and marketing problems associated with this semi-perishable crop.

In developed countries, over the years, and especially since 50s, the percentage of the potato crop used for processing especially for producing French fries has steadily increased. The growth of the fast-food industry since 1960 is the main impetus behind the shift toward use of frozen French fries. In the year 2000-2001 export of frozen potato French fries from three major exporting countries, viz. USA, the Netherlands and Canada, were at a record 2.3 million tonnes. U.S. frozen potato fry exports valued $ 338.315 million in 1999-2000, almost double in value and volume than just six years ago revealing an upward international trend of demand for frozen fries.

In India, home-scale processing of potato to produce chips, *papads*, dehydrated cubes, shreds etc. is common in all potato growing areas. However, there was no visible progress in potato processing under organized sector in the country until 1990. During the last decade growth of organized potato processing became apparent due to the incentives given by the Government. At present there are about 10 processing plants that produce potato chips and fries in the country.

## Export

On export front India's performance had not been commensurate with its global position in potato production. Though India contributes 7.55% to global potato production its share in world fresh potato exports is 0.3% and that for frozen potatoes it is 0.2%. In our own continent, India contributes 21% to total potato production but its export share in Asian market had only been 2% during the last five years (Figure 1). European countries still dominate potato trade even in this part of the world.

**India's Natural Advantages over European Countries for Export:** In European countries fresh potatoes are available only after September whereas, about 90% fresh potatoes in India are harvested during January to March and potato harvesting continues in one part or the other in the country through out the year. The fact that India can supply fresh potatoes round the year and low production cost (due to short crop duration and cheap labour) needs to be aggressively considered for tapping international markets.

Secondly, India is the only country in South West Asia having developed seed production programme. The seed of Indian potato varieties is more suitable for growing in the adjoining Asian countries because; (i) Indian potato varieties, bred to suit sub-tropical climate have performed better in these neighbouring countries than the varieties bred to suit temperate agro-climate of Europe, (ii) potato seed harvested in January/February in India is in perfect physiological state for planting in Asian countries in October/November (European seed harvested in September is dormant), (iii) due to short crop duration, cheap labour and lower transportation costs, price of seed produced in India is also far lower as compared to the potatoes produced in Europe, and (iv) the potato production in India is free from prohibited diseases like potato spindle tuber viroid (PSTVd), potato virus T (PVT), Andean potato latent virus (APLV), tobacco ring spot virus (TRSV), Arracacha virus-B (AVB), potato yellowing virus (PYV), Alfalfa mosaic virus (AMV), silver scurf, ring rot, gangrene, nematodes etc.

**Export of Table Potatoes from India:** Averaged over the last five years (1996-2000) Asian countries annually import about nine hundred thousand tonnes of table potatoes. India's average annual export of about eighteen thousand tonnes to Asian countries during this period is hardly 2%. It is absolutely not commensurate with 21% contribution by the country to total potato production in Asia. India exported table potatoes to 29 countries during last five years. Sri Lanka and Nepal accounted for 61% and 16% of total table potato export from India, respectively. The other important countries that import table potatoes from India are UAE (7.41%), Bangladesh (5.26%) and Mauritius (3.60%). The export of table potatoes from India had been marginal and inconsistent from year to year. Even Bangladesh imported Indian potatoes only in 2 out of 5 reported years. But there is an export on regular basis to Mauritius, Nepal, Singapore, Sri Lanka and UAE. Concerted efforts need to be made to capture the large table potato market (approximately two hundred fifty five thousand tonnes) in these five countries. The main reasons for dismal export of Indian potatoes can be mainly attributed to lack of planned and targeted export policy and suitable infrastructure as well as efforts for identifying assured markets.

**Export of Seed Potatoes from India:** During the last five years (1996-2000) India exported 12,525 tonnes of potato seed to 23 countries. Sri Lanka and Bangladesh alone accounted for 85.5% of total seed export from India. The other regular seed importing countries were Vietnam (2.9%), UAE (2.2%), Singapore (1.4%), Maldives (1.3%) and Nepal (1.2%). However, export of seed potatoes from India was not only marginal but inconsistent from year to year. India being the only country in South West Asia, having a seed production programme, we can emerge as a major seed exporter atleast for this part of the world. Annual potato seed market in SAARC countries is almost over six hundred thousand tonnes. Potato seed produced in India can certainly meet this demand more suitably because of similar agro-climates, varietal adaptability, low cost and right physiological stage of the seed. It is high time that we encash our technological expertise and natural advantage in potato seed production. Therefore, we must popularize Indian potato varieties in SAARC/Asian countries either through technical or research collaborations and/or commodity aid under regional co-operative programmes. To be competitive, we may even think of incorporating potato seed standards developed by the "United Nations Economic Commission for Europe" (Committee for Trade, Industry and Enterprise Development) and "US Export Standards for Seed Potatoes" in our seed production/ certification programme.

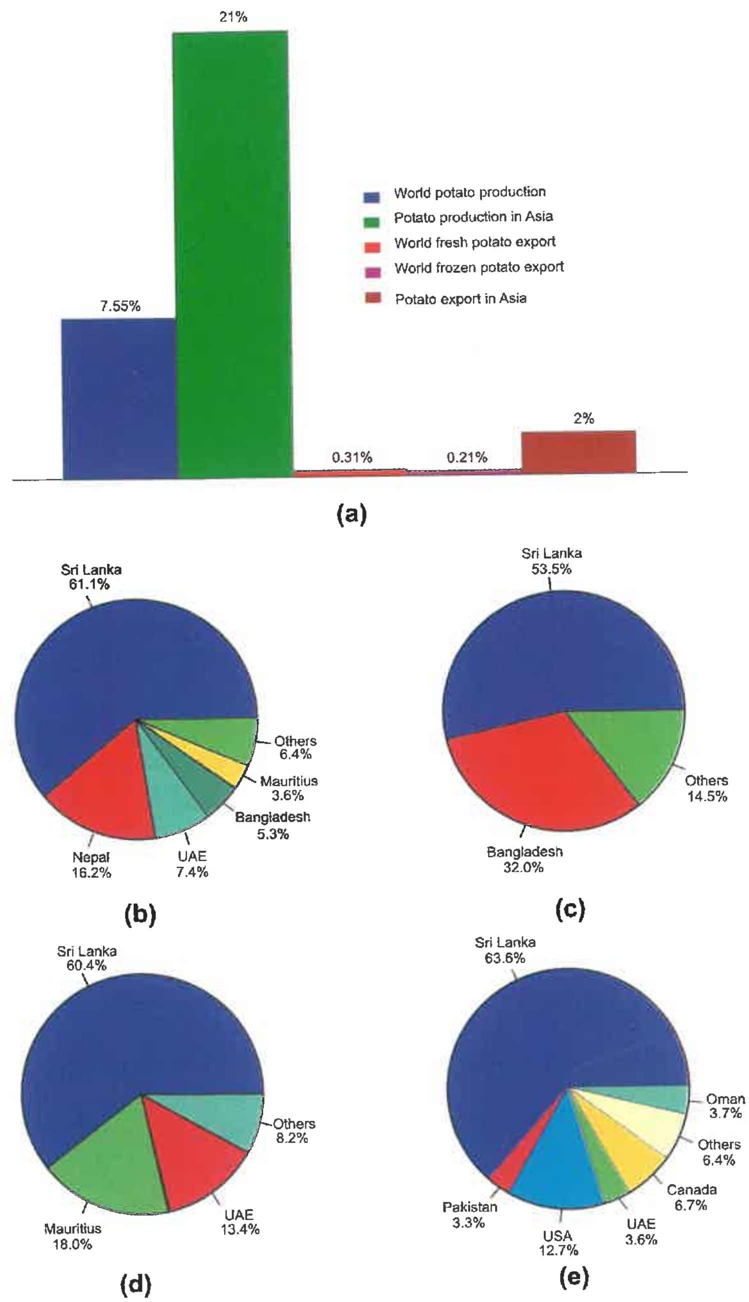


**Figure 1. Scenario of potato production and export from India during last five years (1996-97 to 2000-2001). (a) India's share in global potato production and export (b) Export of table potatoes (total = 91308 t to 29 countries) (c) Export of seed potatoes (total = 12525 t to 23 countries) (d) Export of frozen potatoes (total = 26383 t to 19 countries) (e) Export of other potato products (total = 546 t to 18 countries).**

**(Sources: FAO Database and Monthly Statistics of the Foreign Trade of India. Directorate General of Commercial Intelligence and Statistics, Ministry of Commerce, Govt. of India)**

chuño, a powder prepared from repeated freeze drying, thawing and trampling by men and women folks to squeeze out water and finally dehydrating in hot sun. It was widely used during food shortage and between successive crops during periods of scarcity. Still an important food in the highlands of Peru, chuño has been aptly extolled for its virtues in an ancient Incan adage, "*Stew without chuño is like life without love*".

The Spanish conquerors found potato being very widely cultivated in what are now Colombia, Ecuador, Peru and Bolivia and the Araucanian region of Chile. Following the conquest of Peru, the Spaniards introduced potatoes in Spain (Fig 2) and further spread it to many European countries including Italy, Belgium, Germany, France, Switzerland, and Holland by the end of the 16$^{th}$ century. Initially, potato was grown only as a curiosity in the Europe's botanical gardens and remained a shunned plant-at best food for swine and country bumpkins for next two centuries. It bore the wrath for causing war and lust to tuberculosis, rickets, syphilis and obesity. Often it fell victim to its lineage being member of *Solanaceae* and having hallucinogenic and narcotic cousins like mandrake (*Mandragora spp.*) and deadly nightshade (*Atropa belladonna*) containing scopolamine and atropine like poisonous alkaloids used in ointments said to give witches the power to fly. Potatoes were banned being unworthy of human consumption by the Scottish clergymen as they were not mentioned in the Bible. Possibly the word "spud" (present day English nickname of potato) got its name being acronym for the Society for the Prevention of an Unwholesome Diet, a 19$^{th}$ century activist group dedicated to keeping the potato out of Britain. The first edition (1768-71) of the *Encyclopaedia Britannica* referred to the potato as a "demoralizing esculent", esculent being an ostentatious word for food. Russians referred it as "Devil's apples", while in France potatoes were thought to be fit only for animals and poor people. The potato's struggle for acceptance in Europe took place at every level, from King's kitchens to slum street corners, from the hallowed halls of parliaments to the battlefields of Seven Years' War. Resistance to eating potatoes was so strong in parts of the continent that willing rulers virtually had to force potatoes down their subject's throats. In 1651, Frederick William of Prussia even issued an edict to cut off the nose and ears of any one refusing to plant potatoes. Frederick the Great, still facing resistance more than a century later, sent a wagonload of tubers to peasants in a famine-stricken area, only to receive a petulant reply, "The things have neither smell nor taste, nor even the dogs will eat them, so what use they are to us?" forcing, the great leader to hold an open-air banquet where potatoes were served to prove that they are not only edible, but also fit for royalty. French potato enthusiast Antoine Auguste Parmentier even had to trick peasants into stealing tubers from Louis XVI's Royal Gardens to convince them of the potato's virtues.

The crop remained a botanical curiosity till about the mid-18$^{th}$ century, and was not grown in any Western European country except Ireland, where long suffering peaceful peasantry on brink of starvation sand witched between warring Norman-Irish aristocracy and English relied more and more on the potato as source of food. However, when cattle, food stores, and standing crops were used or destroyed, potatoes being underground escaped destruction. Thus the potato became the "chief food" of the people.

Throughout the 18$^{th}$ century, none seems to have been aware of the danger to the economy of a nation dependent on a single crop when suddenly on one warm, rainy day in August, 1845 an unknown malady (late blight) struck the Irish potato fields. Potatoes quickly rotted in

The native names of the potato also indicate its ancient and widespread cultivation. Thus in the Chibcha language of Central Colombia the names *iomza*, *iomuy*, etc. were used; in Quechua, the language of the Inca Empire, the usual name was *papa*. In Bolivia, the Aymará Indians used the words *amka* and *choque*, whilst in Chile, the Araucanians gave it the name *poñi*. The Spaniards adopted the name *papa* for the potato, which was used throughout their South American colonies. In Europe, neither batata nor papa for potato was ever adopted because the Spaniards first encountered sweet potato, and not having a name for a similar tuber, they used the Indian word *batata*. Subsequently, other tuberous plants that they found in their American colonies were given the same name. *Patata* and potato are clearly cognate forms of *batata*, consequently, the word *papa*, which is still *in vogue* in whole of the Spanish Latin America, never spread outside this area, even though the plant itself is now grown in most parts of the world.

## Early history

In South America, where it originated, potato was main source of food for centuries for the people in the high Andes and southern Chile. Potatoes were dried by Andean Indians to make

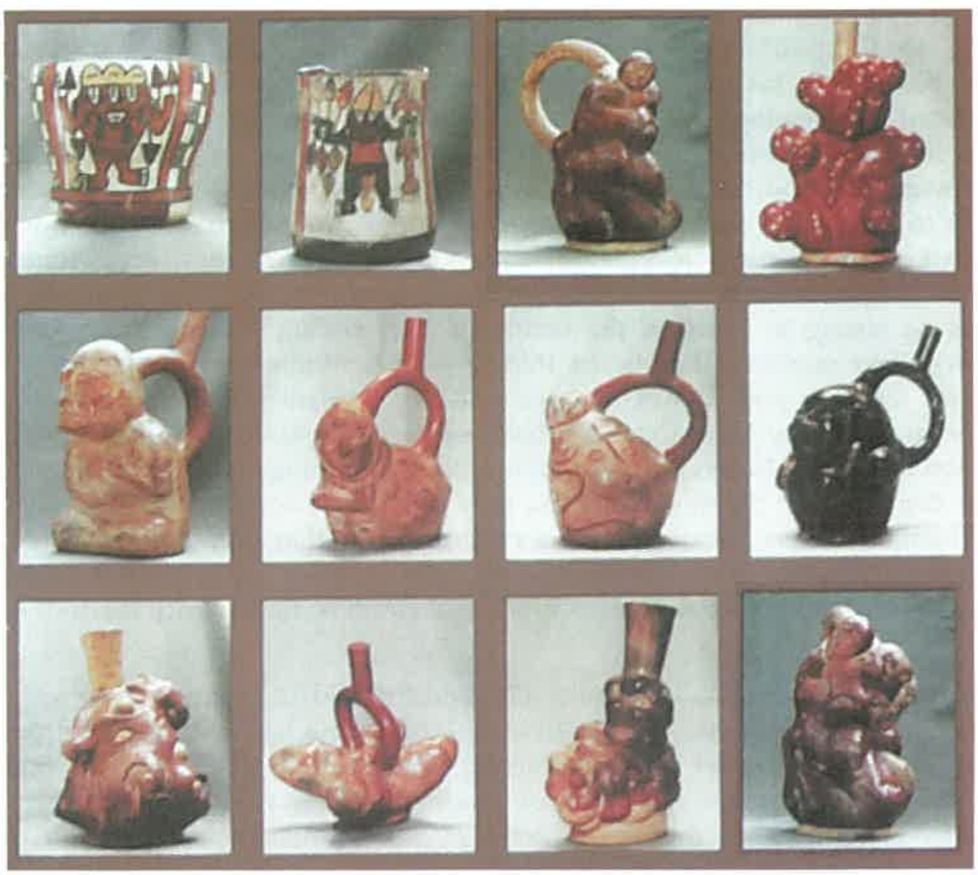

**Fig.1 Ceramics of daily and ceremonial use recovered from Nasca and Mochica cultures.**

**Source: Graves, Christine (ed.). The potato, Treasure of the Andes. International Potato Center, Lima, 2001.**

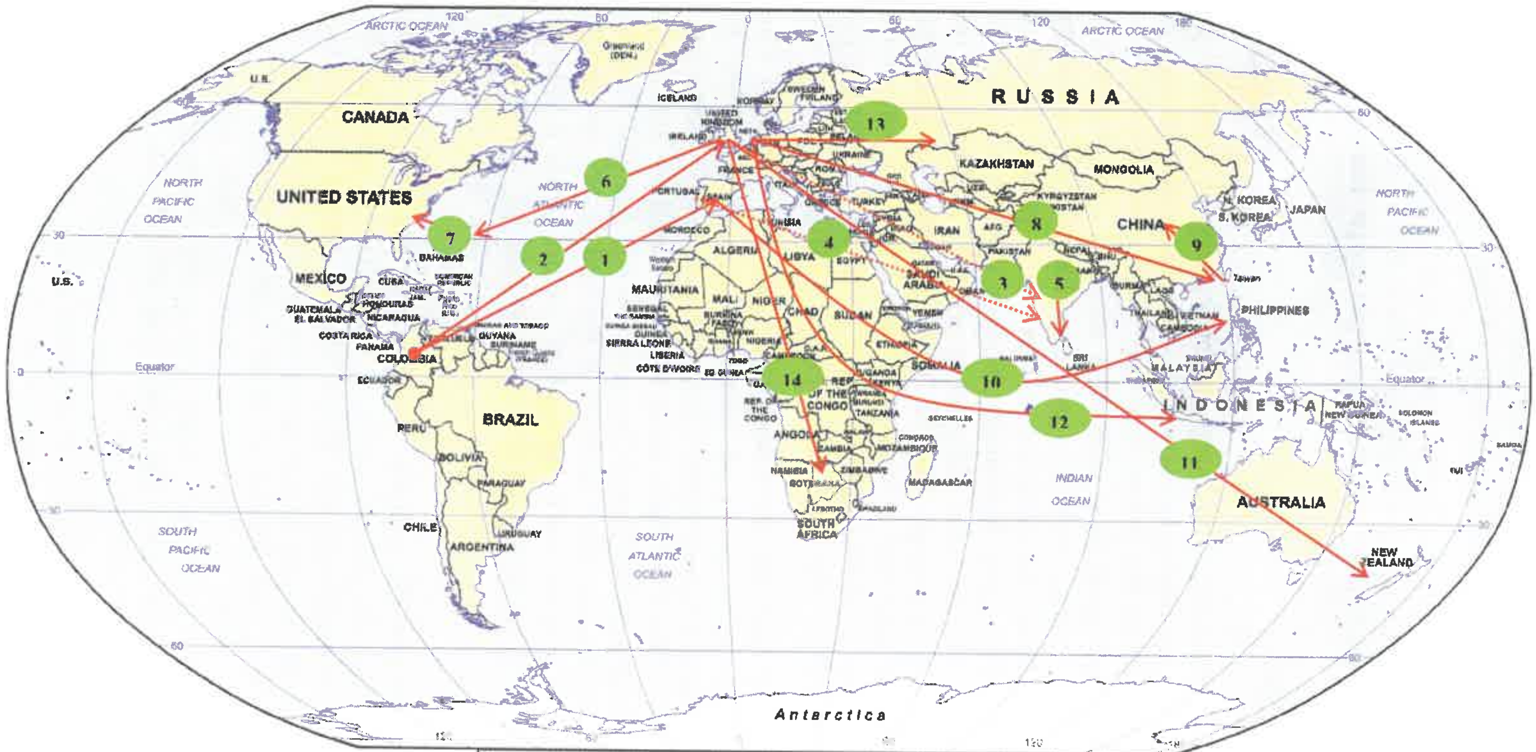


Fig 2 Potato's journey from center of its origin

- South America – Center of origin
1. South America – Spain 1570
2. South America – UK 1590
3. UK – India <1610
4. Portugal – India <1610
5. India – Sri Lanka <1610
6. UK – Bermuda 1613
7. Bermuda – Virginia, USA 1621
8. Holland – Taiwan <1650
9. Taiwan – China <1650
10. Spain – Philippines <1700
11. UK – New Zealand 1773
12. Holland – Java 1794
13. Holland – Russia <1800
14. UK – South African continent 1830

Fig 2 Potato's journey from center of its origin the fields, sending an unbearable stench across the countryside and repeating the same scene across whole of Europe, resulting in famous Irish famine and death of nearly 2.5 million and migration of one million Irish including the famous Kennedys and Reagans to North America.

One of the wars during the Hundred Years war in Europe was christened "Kartoffel Krieg", or the potato war between the Prussians and the Austrians (1778-79) acquiring its name when the contending armies ate up all the potatoes along the battle lines in Bohemia and then called off the fighting.

## Spread in Europe

Though the Spanish chroniclers wrote detailed accounts of the history of their conquests and the life and customs of the people; no contemporary accounts exist (and perhaps none were ever written) of the first introduction of the potato into Europe. Apparently there were two introductions into Europe, firstly into Spain in *c.* 1570 and secondly into England in *c.* 1590. The Spanish introduction rests on market records from the Hospital de la Sangre in Seville, whilst the English records are extremely complex; nevertheless, potato is described and figured in *Herbal* of Gerard, 1597. The early European potatoes came from the Andes, perhaps from the northern Colombian part and were adapted to short (12-hour) days of the Andes and not to long (16-18-hour) days of Europe (Fig 2). These potatoes further evolved through several centuries of 'unconscious' selection in Europe to adapt it to the long summer days of northern Europe and it was not until the late 18$^{th}$ and early 19$^{th}$ centuries, potato cultivation started on a large scale to spread into central and eastern Europe.

From Spain the potato was taken to Italy by the Carmelite Friars and herbalist Clusius (1601) sent it to botanists/herbalists in many parts of Germany and Austria. The Swiss herbalists C. Bauhin and J. Bauhin obtained tubers from Clusius in the late 16$^{th}$ century and sent them to France by about 1600. The Slavic nations seem to have obtained their potatoes from Germany since the names of potato are derived from German ones e.g. *Kartoffel, Grundbirne,* etc. Peter the Great brought the potato to Russia from Holland at the end of 17$^{th}$ century. After the introduction into England in 1590, it was not until the mid-18$^{th}$ century that it was grown on a large scale from where it travelled to Sweden and Denmark in mid 18$^{th}$ century.

## Spread in Asia, Africa, etc

The potato's global voyage began in the 17$^{th}$ century. While stay-at-home Europeans may have had misgivings about the new crop, the sailors, soldiers, missionaries, colonial officials and explorers quickly carried it to their foreign outposts. Thus, Belgian, British, Dutch, French, Portuguese and Spanish sailors carried the potato first to ports in Asia and the South Pacific while trading, whaling and fishing and later inland to their homes. Dutch and French missionaries contributed to its further spread to Taiwan and later to China where it was known by names as "earth bean", "ground nut" and "tuber with many children". The trade route to China passing across Eastern Europe, over the Urals and into the steppes of Asia turned out to be the perfect environment for potatoes.

In the early years of the 17$^{th}$ century, most probably Portuguese sailors took the potato to India, however, they might have been carried by the Britishers to the hills of the north India and to Sri Lanka where it flourished in the colonial home gardens (Fig 2).

In much of Asia, the local name for the potato reflected the nationality of the colonial master, viz. in West Java, the "Dutch potato" where the potato was introduced in 1794 by Dutch people. In 1897 it reached Vietnam, where people called it the "French tuber". Potatoes arrived in the *Himalayas* via the trade routes of the British East India Company and not surprisingly, *Sherpas* called them "English potatoes". The Philippines proved to be an exception and called it *papa* where the Spaniards introduced them in late 1700s. Around the high monasteries of Bhutan and Nepal, Buddhist monks first cultivated potatoes sometime in the 1700s. In the Near East, the tuber found a champion in Sir John Malcolm, a 19th century diplomat who represented Britain at the Ottoman and Persian courts. Fittingly, the potato is known throughout the region as "Malcolm's plum". It is not known exactly when potatoes arrived in South Pacific, but records show that Captain James Cook successfully introduced them into New Zealand on his second expedition in 1773.

The potato arrived in Africa relatively late. A few grew in South Africa as early as 1830, but British and German colonists and missionaries did not introduce potatoes into East Africa until about 1880. In North and West Africa, the two world wars were the main stimulus for the crop's introduction. With supply lines from Europe cut, armies and colonial personnel were forced to grow their own *bombiderres*. While Africa is not a major producer in terms of volume, more African countries grow potatoes today than any other continent.

In the latter half of the 20th century, the crop found a home in the arid Middle East, where it established itself as an important commodity in Jordan, Israel and other countries. It is even grown in climate-controlled facilities in the Gulf States.

In North America, potato was completely unknown until the early 17th century. In fact, this continent first received potatoes from England via Bermuda in 1621 where it was introduced in 1613. The first potatoes were grown in Virginia. Later in the century, there were more introductions from England and Ireland, but no records of an introduction were made from South America before Goodrich (1863) obtained some varieties in a Panama market.

Thus, the potato, which was restricted to the Americas until the 16th century, became one of the most important world crops in no more than some 300 years. Today it is difficult to travel anywhere without encountering a potato.

## Spread in India

The earliest reference of the potato in India occurs in account of the voyage of Edward Terry (1655), who was chaplain to Sir Thomas Roe, British Ambassador to the court of the Mughal Emperor Jahangir from 1615-1619. Terry, in his description of Indian soil and its produce, wrote 'In the northernmost part of this empire they have a variety of pears and apples; everywhere good roots as carrot, potatoes, and others like them....are grown'. Terry's account thus places the potato as a crop in the northernmost parts of India, probably in the hills, earlier than 1615. Similarly, Fryer's travel records (1672-81) mention the potato as a well-established garden crop in Surat and Karnataka in 1675. However, Habib (1963) in his book *The agrarian system of Mughal India (1556-1707)* wrote that ordinary (now called Irish) potatoes were not among the vegetables grown then. According to him mention of 'potatoes' referred to in Terry's (1655) and Fryer's (1672-81) travel accounts actually meant varieties of yams which were grown and formed an article of popular diet in northern and southern India during that period. By late 18th or early 19th century the potato was an important established vegetable crop in the hills and plains of India.

Early potato introductions in India were *S. tuberosum* ssp. *andigena*. There was enormous confusion regarding the identity and nomenclature of these introductions as these were known by different local names in diverse dialects. As a result, during the initial periods of potato research in India, efforts were directed towards identification of such local "*desi* varieties". Based on the studies on various morphological features, duplicate samples were eliminated, and subsequently a few samples were got identified with the help of Potato Synonym Committee, National Institute of Agricultural Botany, England. These efforts led to the identification and characterization of 16 non-European varieties, which came to be known as *desi* or indigenous samples or varieties. These indigenous samples represent survivors of earlier introductions and chance selections in the Indian agro-climates. A list of these indigenous varieties with their salient attributes is presented in Table 1.

**Table 1. Indigenous potato varieties/samples in India**

| Varieties/samples | Salient features |
|---|---|
| Agra Red, Chamba Red, Coonoor White, Coonoor Red, Darjeeling Red Round, Desi, Dhantauri, Gola Type A, Gola Type B, Gola Type C, Phulwa, Phulwa Purple Splashed, Sathoo, Red Long Kidney, Shan and Silbilati | Heat and drought tolerant, therefore cultivated predominantly in the Indian plains; tolerant to degenerative viruses; due to physiological advantages can be stored in country stores during hot Indian summers |

Source: Pushkarnath (1969). *Potato in India-Varieties*, Indian Council of Agricultural Research, New Delhi, 493pp.

Among these, Phulwa, Darjeeling Red Round and Gola, were found to be the most popular ones. These types though no more the mainstream varieties under cultivation now in our country, yet they enjoy consumer preference in small pockets atleast in Eastern India. Besides the indigenous, 38 European varieties were identified from whatever were under cultivation in India before independence. These are referred to as exotic varieties. Not all exotic varieties, however, were commercially important. Only 16 of these had some commercial value (Table 2). These exotic European varieties were naturally long-day adapted and, therefore, their cultivation was restricted to the hills of the Indian sub-continent.

**Table 2. Exotic potato varieties in India**

| Varieties | Salient features |
|---|---|
| Ally, Arran Counsal, Ben Cruachan, Craig's Defiance, Dunbar Cavalier, Great Scot, Italian White Round, Late Carman, Magnum Bonum, Majestic, Northern Star, President, Raeburn's Gregor Cups, Red Rock, Royal Kidney and Up-to-Date | Long-day adapted, therefore suitable for the Indian hills only; multiplication was characterized with progressive accumulation of degenerative viral diseases; physiological limitations on tuber storage and utilization in hot Indian summers |

Source: Pushkarnath (1969). *Potato in India-Varieties*, Indian Council of Agricultural Research, New Delhi, 493pp

# Potato processing : Present status and future prospects

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Potato is the most widely produced and consumed vegetable in the world. It is a good source of carbohydrates (energy), fibre, minerals and vitamins. A versatile tuber can be processed into a range of traditional and modern processed products. It contributes to about 22% of the total vegetables and over 45% of the total root and tuber crops produced in the world (FAO, 2001). Over 80% of the world potato production (308 MMT) is concentrated in the Europe (135.8 MMT) and Asian countries (118.3 MMT) (Table 1). India ranks third (25 MMT) after China (64 MMT) and Russia (34.5 MMT) in potato producing nations of the world (Table 2). The U.P. and West Bengal are major potato producing states in India (Table 3).

India contributes to about 8% of the world potato production. However, the rate of increase in potato production in India is tremendous. The potato production in India has increased by over 1620% during previous 50 years. This is mainly due to development of high yielding cultivars and improvements in production, processing and storage technologies. With increase in production, the issues like creation of storage facilities, marketing, processing and export of potato needs attention of all concerned to avoid the post-harvest losses, glut, fall in prices during harvest season and better utilization of available produce for specific end uses.

## A. COMPOSITION

Potato is a rich source of nutrition, Burton (1966) reported that 100 g fresh potatoes provide 2.1 g protein, 0.3 MJ energy, 25 mg ascorbic acid, 0.1 mg thiamine, 0.02 mg riboflavin,

**Table 1. Potato production in the world**

| Region | Area | Productivity | Production | |
|---|---|---|---|---|
| | 000, ha | t/ha | MMT | % |
| World | 19,301 | 15.9 | 308.2 | 100 |
| Africa | 1,030 | 11.4 | 11.8 | 3.8 |
| NC America | 771 | 34.5 | 26.6 | 8.6 |
| South America | 932 | 14.9 | 13.9 | 4.5 |
| Asia | 7,403 | 16.0 | 118.3 | 38.4 |
| Europe | 9,113 | 14.9 | 135.8 | 44.1 |

Source : FAO Production Yearbook, 2001

0.5 mg nicotinic acid, and 1 mg iron. The tuber composition is markedly influenced by variety, storage, growing season, and soil type (Jadhav and Kadam, 1998). The reported range of potato tuber composition is summarized in Table 4.

Starch is a major constituent (60-80% d.w. ) of potato tuber. The starch contains 18.5 to 32.0% of amylose and about 0.093% phosphorus. Sucrose, glucose and fructose comprise the major sugars in potato. The sugar concentration is higher at the centre of tuber than in the outer region. The nitrogen content of potato ranges from 1 to 2 % of dry weight. The starch and proteins are inversely distributed in the tuber. The salt-soluble globulins are the major storage proteins. A large proportion of total N is contributed by free amino acids that contribute to the browning of products during drying and frying. Potato proteins are rich in lysine than cereal proteins. Potato is a good source of iron, magnesium, potassium and low in sodium, a-solanine and a-chaconine, steroidal glycoalkaloids present especially in peels, sprouts and green tissues often limit the consumption of stored potatoes. These compounds are not destroyed or inactivated by usual cooking procedures (Jadhav and Salunkhe, 1975). The potatoes containing 0.1 % glucoalkaloid (d.w.) are unfit for consumption while those with 0.3% are lethal to human. Hence, proper storage of potatoes to avoid greening and sprouting is important.

**Table 2. Major potato producing countries in the world**

| Sr.No. | Country | Production MMT |
|---|---|---|
| 1 | China | 64.0 |
| 2 | Russia | 34.5 |
| 3 | India | 25.0 |
| 4. | Poland | 20.4 |
| 5. | USA | 20.2 |
| 6. | Ukraine | 13.5 |
| 7. | Germany | 10.9 |
| 8. | Belarus | 8.7 |
| 9. | France | 6.5 |
| 10. | Turkmenistan | 5.4 |
| 11. | Canada | 4.0 |
| 12. | Colombia | 3.0 |
| 13. | Iran | 3.0 |
| 14. | Bangladesh | 2.9 |
| 15. | Peru | 2.8 |

Source : FAO Production Yearbook, 2001

**Table 3. Potato production in India**

| Sr. No. | State | Area 000, ha | Productivity t/ha | Production 000, tons |
|---|---|---|---|---|
| 1. | Utter Pradesh | 421 | 22.6 | 9534 |
| 2. | West Bengal | 318 | 21.0 | 6692 |
| 3. | Punjab | 50 | 18.7 | 942 |
| 4. | Madhya Pradesh | 55 | 15.3 | 841 |
| 5. | Gujarat | 32 | 22.6 | 713 |
| 6. | Assam | 77 | 7.9 | 611 |
| 7. | Karnataka | 28 | 14.0 | 394 |
| 8. | Haryana | 17 | 16.1 | 276 |
| 9. | Bihar | 191 | 8.8 | 168 |
| 10. | Orissa | 50 | 18.7 | 94.2 |
| 11. | Himachal Pradesh | 10.9 | 8.4 | 91.2 |
| 12. | Maharashtra | 15.5 | 4.7 | 73 |
| 13. | Tamil Nadu | 2.9 | 16.4 | 47.5 |
| 14. | Rajasthan | 3.6 | 12.6 | 45.3 |
| 15. | Jammu & Kashmir | 1.8 | 12.3 | 22.1 |
| 16. | Andhra Pradesh | 1.4 | 6.9 | 9.7 |

Source : Indian Agriculture in Brief, 27th Edn.2000

**Table 4. Chemical composition of potato tubers (d.w.basis)**

| Constituent | Reported range % | Average range % |
|---|---|---|
| Starch | 60-80 | 70 |
| Sucrose | 0.25 – 15 | 0.5 – 1.0 |
| Reducing sugar | 0.25 – 3.0 | 0.5 – 2.0 |
| Total N | 1.0 – 2.0 | 1.0 – 2.0 |
| Protein N | 0.1 – 1.0 | 0.5 – 1.0 |
| Fat | 0.1 – 1.0 | 0.3 – 0.5 |
| Dietary fibre | 3-8 | 6-8 |
| Minerals | 4-6 | 4-6 |

## B. STORAGE

The potatoes are generally harvested in February-March. Being perishable, potatoes need to be handled and stored properly before they are used for processing. The method and duration of storage are important for quality of product. Fresh potatoes are available upto April. After this, only stored potatoes are used. The potatoes are generally stored in cold storage at 5-7 $^0$C to avoid sprouting. However, such potatoes are not suitable for processing because they accumulate excessive amount of reducing sugars and spoil the quality of chips (Table 5). Reconditioning of such potatoes does not lower the sugar level or improve the quality of chip to that of fresh potatoes.The potatoes meant for processing are stored at 8-12 $^0$C in the western countries. However, at this storage condition, potatoes sprout. Treating the tuber with suitable sprout suppressant such as CIPC (Isopropyl N-chlorophyll carbonate) checks the sprouting.

Traditionally, potatoes are stored in heaps or *hodi* at ambient conditions covered with plant materials under shade for a month or two. Such potatoes are highly suitable for processing. The level of reducing sugars decrease markedly with concomitant improvement in chip colour when potatoes are held at ambient conditions (Table 6). The level of reducing sugars can be further lowered and chip colour improved when the potatoes are stored in evaporatively cooled structure at 11-27 $^0$C with 75-80% RH (Uppal, 1999).

There is a need to standardize a ideal storage practice for potatoes meant for processing. The system should ensure minimum loss in quality and preserve the initial composition for processing. This involves consideration of climate and weather, design of the storage equipment, control of the environment in the storage, economics and related factors (Salunkhe, 1961). Additionally, the factors such as varietal characteristics, length of dormancy, cultural practices, dry matter at harvest, presence or absence of disease, method of harvesting, sorting and grading of potatoes, removal of field heat and subsequent storage in a container provided with controlled ventilation at about 13-15 $^0$C and 85% RH are important. The International Potato Centre at Lima, Peru has invented ideal storage structures for potato based on provision of diffused light facilities. Further experimentation need to continue to workout the possibilities of precooling of tubers followed by storage of potatoes meant for processing in zero-energy cool chambers. The storage technology that can hold potatoes in acceptable form for processing upto 6 to 8 months needs to be developed.

**Table 5. Effect of cold storage and reconditioning of potato tubers on quality of chips**

| Sr. No. | Storage | Reducing sugars mg/100 g fwt | Chip colour score |
|---|---|---|---|
| 1. | Initial fresh | 230 | 6.0 |
| 2. | Cold storage, 90 days (5-7 $^0$C) | 450 | 9.1 |
| 3. | Reconditioning (10 days at 20 $^0$C) | 317 | 8.1 |

Mean of 9 cultivars. Source : Peshin (2000)

## C. PROCESSING

The literature on potato processing has been extensively reviewed (Marwaha, 1997; Salunkhe and Kadam, 1998). In the developed countries 50 to 60 % of their produce is processed into value added products (FAO, 1995). In India, less than 1% of the total quantity produced is used for processing. Most of the produce is utilized for consumption as fresh potatoes. In the traditional recipes, the washed, boiled, peeled and cut/whole potato pieces are cooked with spices into curried vegetable, mixed with legume flour and fried into range of products. The quality of potatoes with respect to size, shape, specific gravity, eyes, dry matter or level of sugars, amino acids phenolics etc. are not that important for such domestic cooking or fried products. The potatoes stored at 10 to 15 $^{0}$C for upto 6 months can be conveniently used for such domestic processing.

With increased urbanization and involvement of women in employment sector, the processing of potatoes into ready-do-serve snack products or fast foods like chips and french fries is becoming important. In the years to come, potato processing is likely to acquire a significant capital market in India. Further, processing helps in reducing demand for storage, space and adds value to the crop leading to better returns to the growers. The potatoes are generally processed into 1. Fried products viz., chips, French fries, other frozen products 2. Dehydrated products like flakes, dices, granules, flour and starch 3. Canned potatoes and 4. Miscellaneous products like alcohol, lactic acid etc. The quality requirements of raw potatoes for preparation of these products have been defined (Table 7). The tuber size, shape, depth of eyes, specific gravity and contents of dry matter and reducing sugars are some of the important factors that affect the quality of finished product. These properties of tubers in turn are largely influenced by the cultivar, soil/climate under which the crop is grown and nature and duration of storage of the raw potatoes (Marwah 1997; Marwaha, 1999). The quality of finished product is also affected by the method of processing, which include peeling, boiling, slicing, frying oil and temperature, methods of dehydration, packaging procedures and storage

**Table 6. Effect of storage temperature on accumulation of reducing sugar and chip colour**

| Sr. No. | Storage temperature | Reducing sugarmg/ 100 g fr.wt. | Chip colour Score |
|---|---|---|---|
| **Initial quality** | | | |
| 1 | Fresh | 243 | 4.7 |
| **After 90 day storage** | | | |
| 2. | Refrigerated cold storage (3-4$^{0}$C, RH 95-100%) | 2018 | 10.0 |
| 3. | Ambient temp. storage (15-33$^{0}$C, 25-85% RH) | 167 | 3.6 |
| 4. | Evaporatively cool storage (11-27 $^{0}$C, 75-80% RH) | 153 | 3.0 |

Mean of 5 Indian potato cultivars; Colour score upto 1-5 acceptable
Source : Uppal (1999)

**Table 7. Quality requirements for different forms of potato processing**

| Sr.No. | Characteristics | Dehydrated products | French fries | Chips | Canned potatoes |
|---|---|---|---|---|---|
| 1. | Tuber shape | - | Long oval | Round to oval | - |
| 2. | Tuber size, mm | 30 | 50 | 40-60 | 35 |
| 3. | Eyes | Shallow | Shallow | Shallow | Shallow |
| 4. | Sp.gravity | 1.080 | 1.080 | 1.085 | 1.075 |
| 5. | Dry matter, % | 22-25 | 20-24 | 22-25 | 18-20 |
| 6. | Starch, % | 15-19 | 14-16 | 15-18 | 12-14 |
| 7. | RS, % (d.w.) | 2.5 | 2.5 | 1.25 | 2.5 |
| 8. | Texture | Firm to mealy | Firm | Firm to mealy | Waxy |
| 9. | ACD | Slight | Slight | - | Nil |

Source : Sukumaran and Verma (1993)

of products. It is thus, clear that for processing of potatoes into specific product, it is important to define the appropriate cultivar, process conditions, packaging, and storage procedures to make the potato processing a successful and economically profitable business in the developing countries like India.

## I. FRIED PRODUCTS

### 1. Chips

Potato chips, a fried snack food is the most popular form of potato product in the world. The process for preparation of potato chips has been described by several potato workers (Uppal, 1999) and the broad steps are outlined in the flowchart. The golden yellow colour and crispness, yield and oil content are important in potato chips. The medium sized oval / round shaped potatoes with fleet eyes cause lesser peeling losses. The potatoes with higher specific gravity result into higher yields with less oil content in chips (Table 8). The higher dry matter, and particularly low reducing sugars in tubers produce quality chips (Table 9).

**Table 8. Effect of specific gravity of potato on recovery and oil absorption by Chips**

| Sr.No. | Sp. Gravity | Chips yield% | Oil % in chips |
|---|---|---|---|
| 1 | < 1.0599 | 30.1 | 54.4 |
| 2. | 1.0599-1.0633 | 31.7 | 50.4 |
| 3. | 1.0633-1.0707 | 32.3 | 47.0 |
| 4. | 1.0707-1.0782 | 34.6 | 42.2 |
| 5. | > 1.0782 | 35.7 | 38.2 |

Source : Grewal and Uppal (1989)

**Flow chart for manufacture of potato chips**

Round to oval potatoes
↓
Washing
↓
Peeling
↓
Trimming
↓
Slicing
↓
Soaking and washing
↓
Blanching
(60-80$^0$C, 2-5 min)
↓
Partial drying
↓
Frying (180-190 $^0$C)
↓
Salting / Spicing
↓
Packaging

The potatoes with more than 20% dry matter and 0.1% reducing sugars with 0.33 % as upper limit are considered as ideal for fried chips. An equation for predicting the chip colour has been developed. According to the equation, the reducing sugar content of potatoes should not exceed 296 mg/100 g fresh weight to obtain acceptable chip colour (Anon.1993-94). Most of the Indian cultivars possess these levels of dry matter or reducing sugar when fresh. However, only cv. Kufri Sherpa and Kufri Lauvkar were found to produce acceptable chips (Table 9). Recently, two cv. Kufri Chipsona–1 and Kufri Chipsona–2 have been developed especially for chips. These cultivars contain 45 to 100 mg / 100 g fr.wt. reducing sugars in fresh potatoes and they produce excellent chip colour (Table 10). These results indicated that varietal development for lower sugar levels is important for chips.

Secondly, cold-stored Indian potato varieties become unfit for processing into chips within two weeks of storage (Marwaha et al. 1990; Marwaha and Kang, 1994). Storage of such potatoes at high temperatures either in an ordinary farm store or in an evaporatively cooled potato store reduces the sugar level, but the problem is not eliminated (Marwaha, 1994). Further, potatoes stored in such structures for extended period exhibit high weight losses and become unfit for processing (Marwaha, 1996). The reconditioning of potatoes at 20 $^0$C for 2-3 weeks before processing although reduces the sugar level, it is not a reliable solution for high sugar content and for all the varieties due to differences in their response to reconditioning (Iritani and Wales 1978). Cultivars that accumulate less reducing sugar during cold storage viz., *Kufri Sherpa*, FL 1925 have been identified (Uppal and Verma, 1990, Marwaha and Kang,

**Table 9. Dry matter, reducing sugars, free amino acids and chip colour of Indian potato varieties**

| Sr.No. | Variety* | Dry matter % | Reducing sugars mg/ 100 g fr.wt. | Free amino acids mg/ 100 g protein | Chip colour score** |
|---|---|---|---|---|---|
| 1 | Kufri Sherpa | 20.4 | 92 | 76.1 | 2 |
| 2. | Kufri Lauvkar | 19.2 | 128 | 76 | 3 |
| 3. | Kufri Chandramukhi | 20.7 | 208 | 94 | 6 |
| 4. | Kufri Deva | 19.8 | 228 | 87 | 6 |
| 5. | Kufri Bahar | 16.7 | 240 | 105 | 6 |
| 6. | Kufri Jawahar | 19.3 | 246 | 68.8 | 6 |
| 7. | Kufri Jyoti | 17.8 | 264 | 77.4 | 6 |
| 8. | Kufri Sindhuri | 18.8 | 276 | 103 | 7 |
| 9. | Kufri Badshah | 16.9 | 298 | 74 | 7 |
| 10. | Kufri Lalima | 20.6 | 332 | 88 | 8 |

* Fresh produce ** Colour score upto 5 acceptable
Source : Marwaha (1999)

**Table 10. Processing quality of some popular Indian potato varieties**

| Variety | Shape/size | Dry matter % | R.S. mg/100 g fr.wt. |
|---|---|---|---|
| Kufri Chipsona-1 | Oval/large | 21-24 | 45-100 |
| Kufri Chipsona-2 | Round/large | 21-25 | 44-93 |
| Kufri Jyoti | Oval/large | 18-21 | 106-275 |
| Kufri Lauvkar | Round/large | 18-20 | 200-250 |
| Kufri Chandramukhi | Oval/large | 18-20 | 250-324 |

Source : Paul Khurana and Ezekiel (2003)

1994). Other remedies to lower the sugar contents include soaking and washing of potato slices in 2 to 5 % salt solution followed by washing in clean water or blanching for 3-5 min at 65 to 70 $^{0}$C in water before frying. A treatment of 1 to 1.5 mm slices with 5% NaCl, 5% $CaCl_2$, 50 to 100 ppm KMS followed by blanching for 1 min and a dip in 0.25 to 0.5% before frying was found to be quite effective in obtaining good quality chips (Waghmare et al., 1999). Further research need to be continued to workout appropriate processing conditions to obtain golden yellow coloured chips from potatoes with relatively higher sugar contents.

## 2. French fries

Frozen french fries are the most important form of the frozen potato products. These are potato strips of 1 x 1 $cm^2$ in cross section and 6-7 cm in length. They may be either par-fried

or finish-fried by the processor. In the former case, they are later finish fried in deep fat, and in the latter, oven heated before consumption. The steps in making french fries are outlined in flow chart below. The potatoes with long oval shape, shallow eyes with 1.08 sp.gravity, 20-24% dry matter, 2.5% RS (dry weight), 14-16% starch (d.w.) and firm texture are good for preparing french fries. Marwaha et al. (1999) evaluated several advanced potato hybrids for french fries (Table 11). Based on colour, texture, flavour and yield of french fries, the advanced hybrids' MP / 90-83 and MP / 91-G were found most suitable for processing into french fries. All problems with stored potatoes in making quality chips also exist for preparing quality of french fries. Peeling and trimming of potatoes cause a significant (> 20%) losses in weight and nutrients. Hence, methods need to be standardized which use whole washed but unpeeled raw potatoes for processing into products like chips, fries, etc.

Long oval potatoes (50 mm size)
↓
Washing
↓
Peeling
↓
Stripping with cutter (1 x 1 $cm^2$)
↓
Cold water dip and washing
↓
Air drying to remove excess water
↓
Frying at 180 $^0$C for 4-5 min
↓
Packaging
↓
↓ Fresh serve | ↓ Frozen storage
↓
Oven heat and serve

**Process diagramme for french fries**

## 3. Fabricated french fries and chips

Prepared french fries consists of a mixture of dehydrated potatoes and other ingredients that can be constituted rapidly in cold water to form a dough like material. The dough is extruded in square cross sections and cut at a desired length while being extruded. The simulated french fries strips are deep fat fried, resulting in a product uniform in colour, shape, form and texture.

Fabricated chips are prepared from dough of dried potatoes, gelatinized maize, gluten and oil. The dough is shaped into discs, dried to 12% moisture, and deep fat fried. The product

**Table 11. Physico-chemical properties of potato for preparation of french fries**

| Sr.No. | Variety | Shape | Type of tuber eye | Dry matter % | RS mg/ 100 g fr. wt. | Total processing loss | Yield of product % |
|---|---|---|---|---|---|---|---|
| 1. | MP/90-74 | Oval | Fleet | 22.2 | 122 | 14.8 | 53.3 |
| 2. | MP/90-82 | Oblong | Fleet | 18.9 | 124 | 8.5 | 55.7 |
| 3. | MP/90-83 | Oblong | Fleet | 22.1 | 108 | 11.3 | 59.3 |
| 4. | MP/90-86 | Oblong | Fleet | 18.4 | 180 | 12.8 | 46.1 |
| 5. | MP/90-94 | Oblong | Fleet | 21.5 | 104 | 9.4 | 54.0 |
| 6. | MP/90-97 | Oblong | Fleet | 17.8 | 136 | 11.0 | 55.6 |
| 7. | MP/91-G | Oblong | Fleet | 22.5 | 112 | 10.3 | 58.3 |
| 8 | Kufri Bahar | Oval | Deep | 19.4 | 216 | 10.1 | 50.1 |
| 9 | Kufri Jyoti | Oval | Fleet | 18.0 | 245 | 13.9 | 44.7 |
| 10 | Kufri Lauvkar | Round | Deep | 20.5 | 228 | 15.1 | 49.7 |

Source : Marwaha et al. (1999)

**Table 12. Effects of processing method on recovery of flour from potatoes**

| Processing method | Peeling and trimming losses % | Flour recovery % fr.wt. | Flour recovery % d.w. |
|---|---|---|---|
| A | 2.9 | 15.7 | 86.6 |
| B | 13.6 | 14.8 | 81.8 |
| C | 13.5 | 12.7 | 71.1 |

Mean of 11 cultivars.
A. Whole potatoes, pressure cooked, followed by peeling, mushing and drying
B. Peeled whole potatoes, pressure cooked followed by mashing and drying
C. Peeled potatoes, cut into slices of 3 mm thickness, blanched and dried

Source : Marwaha and Sandhu (2001)

exhibit homogeneity or uniformity. The extent of browning can be controlled and flavour modified by use of other ingredients. The potatoes of any size, shape, eyes or sugar contents can be processed into dough. Hence, there is a need to popularize such products over fired chips, which has quite stringent requirement of raw potato quality besides being expensive. Attempts have been made to improve the flavour (Liepa, 1968), texture (Hitton, 1963), crispness (Murray et al. 1971) and shelflife of these fabricated products. Further investigations on improvement in these sensory characteristics are essential.

**Table 13. Varietal variations in dry matter and flour yield of Indian potato cultivars**

| Sr. No. | Cultivar | Dry matter % | Peeling & trimming losses, % | Flour yield, fr.wt. % |
|---|---|---|---|---|
| 1 | Kufri Badshah | 15.7 | 1.7 | 13.5 |
| 2. | Kufri Pukharj | 17.1 | 4.1 | 13.7 |
| 3. | Kufri Sindhuri | 17.1 | 1.9 | 14.2 |
| 4. | Kufri Bahar | 17.3 | 2.3 | 16.5 |
| 5. | Kufri Jyoti | 17.4 | 6.3 | 13.2 |
| 6. | Kufri Lalima | 18.5 | 1.7 | 17.0 |
| 7. | Kufri Sutlej | 18.7 | 3.7 | 16.8 |
| 8. | Kufri Dewa | 18.9 | 2.4 | 16.7 |
| 9. | Kufri Lauvkar | 19.7 | 3.6 | 15.0 |
| 10. | Kufri Jawahar | 20.1 | 2.1 | 18.1 |
| 11. | Kufri Chandramukhi | 20.2 | 2.4 | 18.2 |

Source : Marwaha and Sandhu (2001)

## II. DEHYDRATED PRODUCTS

Dehydration is one of the major means of preserving potatoes, giving products such as raw chips, flour, granules, dice, starch etc.

### 1. Raw chips

Dried potato slices are known as raw chips. These are consumed after frying, salting and spicing. The process is similar to that of fried chips, except that slightly thick slices (1.5 to 2 mm) are prepared and after blanching at 80-90 $^{0}$C for 5-8 min, these are dried under hot sun or solar drier till they become brittle. The creamy white colour of dried chips is important for their market price. For this, the blanched chips are given dip in KMS solution before drying. Both severe blanching and KMS treatment inactivate the polyphenol oxidase and control the browning reactions during drying. Thinner slices dry at a faster rate than thicker ones and black polythene is a better surface for dehydration.

The raw chips seem to be a better approach for processing of potatoes in India. The raw chips (25 to 30% of initial wt.) require less storage space than whole potatoes, exhibit excellent storage life if packaged in suitable pouches, and can be consusmed after frying as per the demand. A large volume of potatoes available in February-March can be processed into raw chips and slices on larger scale to avoid glut and fall in prices. These raw chips also absorb significantly lower amount of fat during frying. The yield of raw chips is generally higher than fried chips. Further, the fried chips are expensive due to sophisticated technology and high cost of frying medium. The control of appearance of colour during frying is difficult for fried chips. The browning begins when the moisture contents of chips falls below 6% and continues till final chip moisture reaches to 2% in frying pan. In raw chips, these are already dried. Hence, extensive frying is not required. The creamy white colour of raw chips is generally maintained during frying. The fried chips are however crispier and attractive while the raw chips remain brittle even after frying. Further research is needed to improve the crispness of raw chips after frying, and on development of suitable solar drying system for raw chips.

## 2. Dehydrated potato cubes

It is convenient to preserve potatoes in the form of cubes, and packed in airtight containers, these can be stored for 10-12 months at ambient conditions. Such dried cubes can be reconstitutes by soaking in warm water and used when fresh potatoes are not available in the market. The procedure for preparation of potato cubes is outlined in the flowchart. The trimming losses are usually 20 to 25 % depending on the variety. The sun drying with black polythene for 2 days is enough to obtain dried cubes. Further experiments are needed to improve the recovery and reconstitution properties of the dried product.

### Flowchart for Preparation of potato cubes

Large, oval / round potatoes
↓
Washing
↓
Peeling
↓
Trimming
↓
Cutting (1 $cm^3$)
↓
Washing in water
↓
Blanching (80-90 $^0$C, 10 min)
↓
KMS (1%) dip, 10 min
↓
Drying
↓
Packaging in air tight container

## 3. Potato granules

The granules are prepared from cooked and mashed potatoes. They can be reconstituted to a texture that is both dry and mealy or moist and creamy, according to individual preference. The steps for preparation of potato granules are outlined in the flowchart. In this process, cooked potatoes are partially dried by adding back previously dried granules to give a moist mix, which after holding, can be satisfactorily granulated to a fine powder (Talburt et al.1987). A method for the production of granules by a straight through freeze-thaw process without

### Add back process for producing dehydrated granules

Preprocessing operations
↓
Slicing and washing
↓
Water blanching
↓
Cooling
↓
Steam cooking
↓
Mashing, mixing, sulfiting and other additives ←
↓
Conditioning
↓
Air-lift drying
↓
Sieving
↓
Fluidized bed drying
↓
Granules

**Table 14. Properties of starches from Indian potato varieties**

| Sr. No. | Cultivar | DM % | Starch yield % | Mean granule size, µm | Amylose % | Viscosity (4%) CP |
|---|---|---|---|---|---|---|
| 1. | Kufri Chandramukhi | 21.4 | 11.4 | 59.6 | 23.7 | 386 |
| 2. | Kufri Jyoti | 18.4 | 9.0 | 52.5 | 17.2 | 651 |
| 3. | Kufri Sindhuri | 20.4 | 10.1 | 45.0 | 19.2 | 350 |
| 4. | Kufri Lalima | 20.2 | 11.4 | 45.0 | 18.6 | 353 |
| 5. | FL 1533 | 23.0 | 12.6 | 40.0 | 18.1 | 516 |
| 6. | Corn starch | - | - | 10.0 | 29.7 | 64 |

Source : Peshin (2001)

add-back of a large proportion of the product has been described (Ooraikul, 1973). The freeze-thaw granules exhibit higher water holding capacity, lower bulk density and larger particle size than those do from the add-back process. The use of potatoes with low sugar content, drying the product to low moisture content, use of antioxidants and packaging with $N_2$ flush in sealed pouches improves the shelflife of granules.

## 4. Potato flour

It is prepared by dehydration of peeled, cooked potatoes to the desired fineness. The steps in preparation of potato flour are outlined in the flowchart. Marwaha and Sandhu (2001) tested three methods for preparation of potato powder. It was observed that the peeling and trimming losses were minimum and flour recovery was maximum when whole potatoes were first pressure cooked followed by peeling, mashing and drying (Table 12).

**Process for preparation of potato flour**

Whole potatoes
↓
Pressure cooking
↓
Peeling
↓
Mashing
↓
Drum drying
↓
Grinding
↓
Packaging

Potato flour is available in two forms: granules and fine flour. It is widely used in bread, cookies, doughnuts, cake and cookies mixes, dehydrated soups, franckfurters, gravies, sauces, baby and snack foods to the extent of 5%. It improves the water absorption, tenderness, and freshness of the products. Marwaha and Sandhu (2001) evaluated 11 popular Indian potato cultivars for flour yield (Table 13). The flour yield was found to be related to dry matter content of the tubers. The DM content ranged from 15.7 to 20.2 % in 11 cultivars. The cultivar Kufri Jawahar, Kufri Lalima and Kufri Chandramukhi were found to produce higher yield of potato flour.

## 5. Potato starch

Starch is a major (65 to 80 % d.w.) component of potato tubers. It is widely produced in European countries. The potato starch exhibit significantly different rheological characteristics than other plant starches. The granule size, amylose content, molecular size, phosphorus content and degree of branching of potato starch are characteristically different than other starches. The food and industrial uses of potato starch have been reviewed (Marwaha, 1997, Peshin, 2001).

Peshin (2001) evaluated 6 popular Indian potato cultivars for recovery and properties of starch (Table 14). The yield of starch ranged from 9.0 to 12.6 %. The starch exhibited a granule size of 40-59.6 mm, amylose content of 17.2 to 23.7% and viscosity (4% solution) of 350 to 651 CP, and P content of 0.09 to 0.10 %. It was indicated that this starch can be effectively used in textiles, food, paper and pharmaceutical industries (Joshi and Kulkarni 1993). The surplus and damaged potatoes, available during gluts, can be used for preparation of starch.

## III. TRADITIONAL PRODUCTS

Potatoes are widely processed at domestic level to prepare products that have ethnic values. The products like noodles, shreds, *chakali*, *papad* etc. are quite popular among the Indian populations. Although quantitative estimates are not available, a large proportion of potatoes are processed and utilized in these forms. The morphological and chemical qualities of raw potato to prepare such products are not quite stringent.

## IV. CANNED PRODUCTS

Potatoes are canned in different forms including whole, diced, sliced, strips and julienne. A good canning potato should not slough or disintegrate during processing. Potatoes of low specific gravity (< 0.075) are preferred for canning. The use of $CaCl_2$ tends to firm the tissues and prevent sloughing during storage. The smaller size tubes separated during size grading can be best utilized for canning in 1 to 2 % brine solution after washing and peeling. Such canned potatoes are quite suitable for defence personals stationed at remote hilly and ice areas and during non-availability of raw potatoes in the market.

## V. DOMESTIC UTILIZATION

In India major potato produce (> 95%) is utilized at domestic, restaurants, hotels and hawkers' level for daily fresh consumption. The common products are curried potato pieces alone or with mixed vegetables, spiced potatoes vegetable, pakodas, vada, pattice etc. Since the potatoes are peeled and cut into suitable pieces, mixed with spices, legume flour and other ingredients before cooking or frying, their dry matter, reducing sugar, sp. gravity, size and shape etc. do not affect the recovery and quality of products to any significant extent. Even potatoes stored at 12 to 20 $^{0}$C are safely used for domestic consumption without any conditioning etc. It is thus clear that most cultivars, otherwise not suitable for processing into sophisticated products like chips and french fries, are best used for preparation of products like domestic fresh products, flour, starch, reconstituted chips and fries.

## VI. PROCESSING AND NUTRITIONAL LOSSES

### 1. Peeling

Peeling of potatoes is often practical to obtain a product of superior quality. The losses in weight have been found to be 6% for raw, 2% for boiled and 10% for baked potatoes due to peeling (Augustin et al. 1979). The average peeling losses to the tune of 5 to 25 % have been recorded (Treadway, 1987). It also causes a marked losses in minerals, crude fibre, riboflavin, and amino acids (Augustin et al. 1979; Mondy and Pounampalam, 1983; Talley et al. 1983). Hence, it is suggested that for commercial processing into chips or fries peeling may be avoided and for all other products, peeling should be done only after boiling.

**Table 15. Percentages of weight changes and vitamin C. retained in Canadian potatoes after different types of cooking**

| Preparation | % Weight changes | % vitamin C retained |
|---|---|---|
| Boiled in skin | 94 ± 2 | 81 ± 10 |
| Boiled pared before cooking | 99 ± 2 | 73 ± 8 |
| Boiled, mashed + milk | 120 ± 2 | 77 + 10 |
| Boiled, mashed + margarine + milk | 123 ± 2 | 72 ± 12 |
| Boiled, browned | 72 ± 2 | 28 ± 11 |
| Fried | 57 ± 5 | 72 ± 14 |
| Baked | 85 ± 2 | 78 ± 9 |
| Raw, browned | 68 ± 4 | 60 ± 13 |
| Scalloped ± cheese | 123 ± 6 | 80 ± 15 |
| Scalloped | 113 ± 6 | 68 ± 10 |

Source : Pelletier et al. (1977)

## 2. Boiling and steaming

Cooking potatoes by boiling increases the starch digestibility (Hellendoom et al.1970). However, potatoes are known to contain a significant proportion of starch that is resistant to enzymatic hydrolysis (Jone et al. 1983). Boiling of peeled potatoes exhibit greater losses in nitrogen than boiling of unpeeled potatoes (Choudhari et al. 1963). The losses in ascorbic acid, B-complex vitamins or minerals are generally lower in steamed potatoes as compared to boiled ones.

## 3. Frying and baking

Frying of chips from fresh raw potatoes or pieces of boiled and peeled potatoes in oil or microwave ovens removes moisture and concentrates the nutrients. The frying of potatoes results in significant losses (> 40%) in ascorbic acid (Fenton, 1940). Potatoes are generally baked with their skin. Baking of potatoes is known to cause 20 to 30 % losses in ascorbic acid (Pelletier et.al., 1977).

## 4. Microwave cooking

In conventional cooking, heat is applied to the outside of food by convection, radiation or conduction and then conducted to the interior of the food. Heat generated from within the food by a series of molecular vibrations in the basis of microwave cooking. Microwave cooking is however reported to cause greater cooking losses and decreased palatability (Korschgen et al.1976). The effects of different cooking methods on changes in weight and vitamin are summarised in Table 15. The cooking method used has a significant effect on the retention of vitamin C, with boiled potatoes retaining about 80% compared to only about 30% for hashed browns.


**Plate : Comparison of prepared potato chips with market samples.**

A) Rahuri local chips

B) Hello chips

C) Kufri jyoti chips

D) Uncle's chips

## D. CONCLUSIONS

India ranks third in the potato producing nations of the world and contribute about 8% of the world potato production. The potato production in India has shown phenomenal increase in recent years. This warrants a need of developing suitable postharvest technologies for handling, storage and processing, and planning strategies for marketing and export of raw and processed potatoes. Over 95% of the potatoes produced in India are currently used at domestic, restaurant or hawkers level to prepare traditional products for daily consumption. However, with rapid increments in production, the processing sector is fat expanding. With introduction of WTO policies and regulations, several foreign concerns are entering into potato processing in India. Hence, a share of total produce for processing sector may increase markedly in the years to come.

Potatoes are harvested in February-March in India. Fresh potatoes are available only upto April end. Thereafter stored potatoes are used both for domestic and in processing sectors. Both morphological and chemical characteristics of tubers affect the storage and processing properties. The potatoes with medium to large size, oval to round shape, shallow to fleet eyes, higher specific gravity and dry matter, with lower levels of reducing sugars, phenolics, free amino acids and polyphenol oxidase activities are better suited for processing into chips and fries. These characteristics are influenced largely by the cultivars as well as method and duration of storage of tubers. A commendable work has been done with respect to development of new potato cultivars suitable for particular end use and their testing at CPRI, Shimla, India.

Potatoes are mainly processed into value-added commercial products viz. fried chips and french fries and reconstituted chips and fries. The quantitative share of potato processing into dehydrated products like raw chips, slices, diced potatoes, potato flour, potato starch, granules and canned potatoes etc. is increasing. The french fries and fried chips are liked most by the consumers for their golden yellow colour, flavour and crispness. However, these products are highly expensive and generally beyond the reach of common consumers. These products also need a quite stringent quality parameters of raw potatoes, which are generally available only in fresh produce of particular cultivars.

Potatoes stored in traditional storage like heaps or *hodi* at ambient conditions for 1 to 2 months are excellent for processing. The potatoes stored at 12-15 $^0$C for 2-3 months remain acceptable for processing while those held at 2-5 $^0$C are unfit for processing into chips or fries even after reconditioning. In order to avoid the glut and fall in prices during harvest season, potatoes need to be procured, collected, graded for size and shape, held at 15 $^0$C after treatments like precooling and processed into products like fried chips, french fries upto 2 to 3 months and latter into dehydrated products like raw chips, flour, starch, granules, cubes, reconstituted chips and fries, and into canned potatoes.

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# Potato marketing - problems and solutions

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## 1. INTRODUCTION

Potato is one of the most important food crops in the world. This crop occupies the largest area among vegetables. In India, though potato was introduced during late sixteenth or beginning of seventeenth century, its commercial cultivation and consumption in large quantities began only from 1932. Thereafter, with enhancement of technology and infrastructure improvement, the area under potato cultivation increased and its production registered increase more than four folds. The steady and rapid increase in production of potato has created numerous marketing problems too.

Efficient marketing of farm produce is absolutely necessary both from producers view as well as consumers view. On one hand, it provides enough incentives to the farmers to increase agricultural production and on other it offers the produce to consumer at reasonable prices. Our country became surplus of potato way back in the early 1970s but not much new outlets have emerged to utilize the surplus gainfully. In this paper, an attempt has been made to identify the problems related to marketing of potato and suggest possible solutions for them.

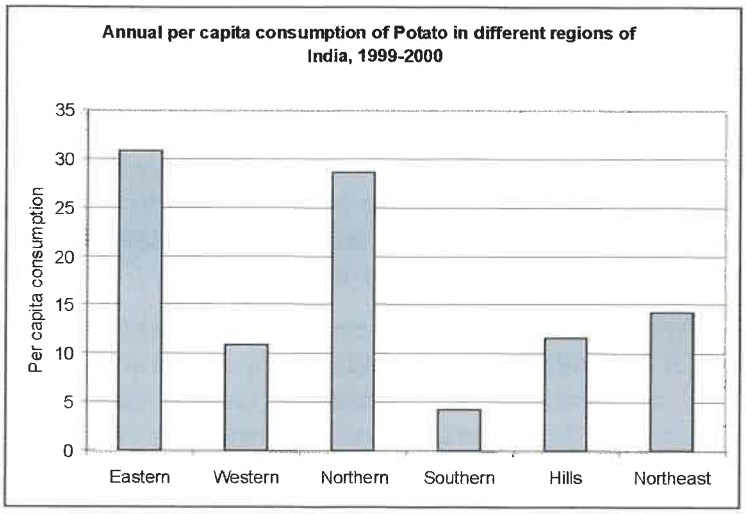
## 2. DEMAND AND SUPPLY

With increase in population and income, the demand for potato is increasing in the country. Since the per hectare food value (calorie-protein) of potato is very high, it can widen the food supply base and thus can reduce the excessive dependence on too few crops for subsistence (Mruthyunjaya, 1982). The data of NSSO rounds show that the demand for potato is more in rural areas than urban areas. In our country, urban areas are exhibited to be having more diversified food basket than rural areas. The urban occupations are generally sedentary which require low energy food. It is also believed that potatoes are responsible for obesity and heavy to digest food. It is also reported that 50-60% of the consumers were advised not to eat potatoes during illness by their doctors (Pandey et al, 1999). Moreover, with increase in income, people will go for high cost commodities like cheese, mutton, chicken, etc. These are some of the factors, which are reported to be responsible for low demand of potatoes in urban areas.

India entered into rapidly expanding phase of potato production during 90s and has emerged as the third largest producer of potato in the world (Business line, 22 June 2002). The growth rates of potato have not only been increasing, but they have exceeded the growth rates of other major food commodities like rice and wheat. The production of potato has registered highest growth in the period of 1991-2001 i.e. 4.8%. Though potato is cultivated in almost all parts of the country, yet it's supply is mainly from Gangetic plains comprising Uttar Pradesh, West Bengal and Bihar. Uttar Pradesh is the largest supplier of potato in the country and occupies recorded largest area under potato cultivation.

## 3. CONSUMPTION

Potato is the most important vegetable in India. Its share in consumption of all root vegetables is about 60 per cent. Potato is an important source of carbohydrates and its consumption is also the highest among all vegetables. Consumption of potato shows variation across different regions of India (Figure 1). The annual per capita consumption of potato is significantly higher in Eastern and Northern region whereas it is considerably low in the Southern region. The reason for low consumption may be that the Southern states do not favour potato to a large extent (Kumar et. al 2002).




The consumption of potato per head is very low in India as compared to that of Western Countries. The potato consumption per capita in India is 14.8 kg/head/year, which is the lowest in the World (Paroda, 1999). Potato is consumed primarily as a vegetable rather than the staple food. The Consumption data of NSSO rounds show that the potato is a staple food of poor. In rural areas, per capita consumption of potato for 30 days has risen to 1.61 kg during 1999-2000, which was 1.18 kg during 1987-88. The consumption pattern of potato in urban areas also registered an increase but the magnitude is lower than the rural areas. The per capita consumption of potato in urban areas was 1.11 kg during 1987-88 and has risen to 1.32 kg during 1999-2000.

Annual per capita consumption of potato for the country as whole is reported at 17.79 kg during 1999-2000, which constituted about 24 per cent in total vegetables consumption. Annual per capita consumption of potato in rural India is 18.87 kg whereas in urban areas it is found to be 15.98 kg during the same period (Kumar et al, 2002).

## 4. STORAGE

Proper storage of potato is necessary not only for realizing better prices but also for regular supply. Storage practices play a very important role in the process of its supply and regulating prices. In India, potato is grown under all types of agro-climatic conditions ranging from sea level to snowline. Depending on the climatic conditions, quantity, quality and seed variety, farmers use different storage methods. In Northeastern India, farmers store small quantities of their produce for market and domestic use at room temperature. Housewives periodically inspect tubers and get rid of tubers, which are going to rot soon. In Semi-arid regions, where the probability of rains for two to three months after harvest is negligible, farmers use heap method. Potatoes are stored in the forms of heaps of 20-30 kgs under the shade of a tree and are covered by potatoes haulms. Bamboo racks and pits are some of the other common methods used in India. Though traditional methods of storage have several advantages like these are cheap and only minimal investment is required; the materials required are locally available; the systems are readily acceptable to farmers yet it is estimated that post harvest losses due to traditional methods range from 15-80 per cent depending on the method and region (Ezekiel et al, 1999). A study by Atteri (1995) revealed that the post harvest losses of potato is 13.8%. It is also estimated that among the vegetables, potato records maximum post harvest losses at retail market level (5.75%) and at storage level (4.0%). Moreover, since the potato tubers consist of about 80 per cent water and are living organs, make them vulnerable to storage losses.

India now gives greater consideration towards improving post-harvest storage systems to minimize the loss. The storage is necessary both to regulate the supply of ware potatoes to the market and to minimise gluts and distress for potato producers, and, to store the seed (Ezekiel et al, 1999). In India, frequent glut like situation appears which forces growers to leave their crop un-harvested. There are frequent incidents of farmers putting their produce in cold store but after some time, no one is turning up to claim it back as the storage charges are higher than the selling price. New incidents of protests are reported as they dump their produce and block busy roads in near-by towns.

When the tubers are dormant and conditions are dry, its relatively easy to store potatoes under non-refrigerated conditions for 3-4 months. However, once the monsoon season begins, non- refrigerated storage methods are no longer suitable. Furthermore, most of the Indian potato varieties generally have a dormancy period of about 6-8 weeks, and once the dormancy period is over, sprouts will emerge (Ezekiel et al, 1999).

For seed potatoes, it has become standard practice to store the seed at 2-4°C, because at this temperature, sprouting does not occur and weight loss is minimal. However, for ware potatoes, a storage temperature of 8-12°C is preferable, for during cold storage, ware potatoes accumulate reducing sugars and sweeten. Furthermore, when the potatoes are taken out of cool storage, they begin to sprout and rotting increases, thereby reducing their shelf life and acceptability to consumers and processors (Paroda, 1999)

Cold storage facility is insufficient and ill-suited to the requirements of potato growers. It was estimated that India currently has cold storage capacity of 10.3 million tones to store about 45% of total production (Paroda, 1999). It was also estimated that the capacity to store another 1.2 million tons is urgently required with a further 800,000 tons of capacity requiring upgrading (Singh, 1999). However, the dependence on high-energy refrigerated storage systems is believed to be not sustainable in the long term (Paroda, 1999). After de-regulation by the state governments, cold storage costs have increased, adversely affecting returns to producers and increasing the cost of potatoes to consumers.

## 5. TRANSPORTATION

Efficient transportation is an extremely important marketing function as it enables the movement of farm produce to the wholesale markets, warehouses, distribution centers and finally to the consuming points and even to export points. In order to enable the producer to market his produce efficiently, it is necessary that markets are very well connected with feeder roads with the villages. Punjab, Haryana and Kerala are the only states where almost all villages have been connected with all-weather roads whereas the situation in other states is not satisfactory. Linking of all villages to the markets has become more essential to benefit farmers from increasing production of perishable crops.

The retail price of vegetables in major cities is higher than the price in other cities. For instance, the retail price of potato in major cities ruled at Rs. 3.50 to Rs. 5.00 per kg during 1997-98, while in states like Bihar, W.B. and U.P. they were available at throw away prices like 2-2.50 per kg. This indicates totally unsatisfactory movement and distribution.

Table 1. Percentage increase in retail prices over wholesale prices of potato (year wise)

| Markets | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|
| Bangalore | 50 | 46 | 58 | 43 | 54 |
| Mumbai | 40 | 36 | 72 | 49 | 69 |
| Calcutta | 31 | 30 | 54 | 17 | 41 |
| Delhi | 39 | 34 | 64 | 41 | 56 |
| Chennai | 63 | 62 | 86 | 54 | 79 |

Source: Wholesale and Retail Marketing of Fruits and Vegetables in Metropolitan Cities, NHB, Ministry of Agriculture, GOI

Rail and roads are the major means of transportation of agricultural produce to various consuming and assembly points. These means of transportation are highly inadequate and outdated, which result in considerable transit losses of specially perishable produce like potatoes. There is an urgent need to develop suitable and specialized road and rail transportation. Adequate air transport facilities are also required to enable our exporters of floriculture, horticultural and other perishable products to meet commitments of quality and time in international markets.

## 6. MARKETING MARGINS

Marketing cost is an important item determining the share of profit of the farmers in the price paid by the consumer. A study by Babu Singh et al in year 1998 calculated the share of producer, wholesaler and consumer in the marketing cost of potato for Farrukhabad district of Central U.P. They found that the total cost in the marketing of potato came to Rs. 82 per quintal, of which the cost incurred by the producer was the highest, being 49 per cent, followed by the wholesaler (36 per cent) and the retailers (15 per cent). It was also reported that the producer's share in consumer's price came higher in off-season/post-storage period than pre-storage/harvest period. The marketing charges paid by the producer was the highest during pre- and post-storage period, whereas charges paid by wholesaler and retailer came next to it.

Another study by Verma and Rajput (1998) in Indore district of Madhya Pradesh revealed that the producer's share in the consumer's rupee in the marketing of the produce in the mandi was 65 per cent. The low share of the producer was mainly owing to higher marketing and transport charges and higher middlemen's charges.

In a study by Singh and Sharma (1998) in Western U.P., important cost items in the total cost of marketing on different categories of farms were identified. The farmers incurred the highest expenses in the sale of potato in distant markets during May-August after storing in cold stores, followed by sale at cold stores during September-November while it was the lowest in the case of sale at the farm itself during January–March. Across the farm size-groups, the cost of marketing of potato at all places and time was highest in the case of large farms while it was the lowest for small farms.

## 7. MARKETING AND PROCESSING

The profitability of a crop is largely determined by the costs of production, market prices and the marketable yield (after discounting post-harvest losses). As both production and productivity per hectare of potato have increased, net returns to farmers have decreased. An analysis of past data suggests that an annual growth rate in production exceeding 8% will induce a glut in the market, whereas an annual growth rate below 3% will lead to a shortage (Singh, 1999). Our country has faced severe gluts in 1975, 1979, 1982, 1985, 1987, 1988 and 1997 when net returns to farmers decreased by as much as 27% (Dahiya and Sharma, 1999). During 1996-97, there was bumper crop of 24 million tons in the country, the price in major markets had plunged to as low as Re. 1 per kg which was not enough to meet the cost of even harvesting and transportation.

The bumper production and inadequate cold storage facilities are primarily responsible for the heavy economic loss to farmers. It is also indicative of an inelastic demand in case of potato.

Netherlands, USA and Canada are the world leaders in the production and export of processed potato products. USA processed about 60% of its produce. In India processing of potato is still in its infancy. We have installed capacity to process only 0.3 % of our output in the organised sector. It is reported by Marwaha and Sandhu (1999) that processed potatoes currently constitute less than 0.5% of its annual production. While the consumption of processed potato products is anticipated to increase, at present, the processing sector is largely comprised of various kinds of dehydrated potato products, most often produced using traditional methods of processing (Paroda, 1999). On reconstitution, these products are used in the preparation of various dishes including *samosas* and *masala dosas* and potato flour is used in the preparation of *tikkis*, *idli* and *alu bhujia*.

Nevertheless, there are other constraints to the development of potato processing in India. Not all varieties are suitable for processing. When many of the European and North American varieties used for processing are grown in India, the yields achieved are low, the dry matter is low, but the reducing sugars are high (Paroda, 1999). When such potatoes are processed, not only is the recoverable yield low, but the product is often discoloured to an unacceptable level. In 1998, CPRI released two new varieties; Kufri Chipsona 1 and Kufri Chipsona 2, both of which have resistance to late blight and are better adapted to the short-day growing conditions in India (Gaur et al, 1999). However, the lack of adequate storage facilities and inadequate infrastructure to facilitate the transportation and marketing of processed potato products continues to impede the development of large scale potato processing in India (Paroda, 1999).

## 8. ALTERNATIVE MARKETING OPPORTUNITIES

While increasing attention is also being directed towards the development of export markets and the potato processing sector as an additional means for disposing of the surplus production, experience suggests that such a strategy is fundamentally flawed. The needs of both modern potato processors and export markets are often very specific with regard to the variety, tuber size, skin colour and flesh colour. Furthermore, such international markets generally require a consistent supply of high quality tubers that are competitively priced. It is simply not possible to develop a long-term market where potato producers are entering and exiting the market in response to prices paid in the domestic market.

## 9. CONCLUSIONS AND SUGGESTIONS

India is the second largest producer of vegetables in the world and India occupies the third rank in the production of potato. India has made significant improvement in the production of potato and has potential to increase its productivity further. It generates the employment opportunities and provides additional income to the farmers. India could earn substantial amount of foreign exchange by exporting potato.

**Some suggestions are:**

1. Proper linkages between producing and consuming markets should be established to balance the demand and supply situation.
2. Infrastructure has to be improved to store the surplus produce
3. During bumper crop year, the farmers abandon their produce lying in cold stores, as the cost of paying for the cold storage is higher than the whole-sale price in different mandies in the country. Some steps should be taken by government to control this condition.
4. Processing infrastructure has to be improved to bring value addition to the produce and to minimise the post harvest losses.
5. Support price policy should also be there, so that growers get profitable price for their produce and consumers get produce at reasonable prices
6. Export oriented marketing research should be taken up on priority
7. Urgent need to adopt some workable and unconventional uses of potatoes like manufacture of alcohol and the industrial uses from potato

8. There is no sustainable national policy for export of potato. So, Government should design long-term export policy to encourage its export.

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# Potato development and government support for increasing production and export

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## INTRODUCTION

The Potato is one of the most important commercial and highly productive vegetables grown and consumed almost all over the country. In India potato has been recognized as cash crop in 1949. During very short span the crop gained popularity and availability is now considerably increased to meet the demands. Potatoes are used as food and cooked in various ways in all kitchen in different parts. Potatoes are also dehydrated in the form of chips, shreads and different other processed forms for use by all sectors. Potatoes are highly nutritious and form a rich source of carbohydrates and vitamin C. The availability of cold storages for potato made their availability all the year round apart from their production in different seasons in different parts of country although rabi is the main season of potato cultivation in major potato growing states.

## AREA, PRODUCTION AND PRODUCTIVITY

A global review of area and production of major vegetables shows that potato ranks first in area (19306725ha) and production (304392708MT) of vegetables in world among nine major vegetables namely onion, potatoes, cauliflower, green peas, cabbage, tomatoes, okra, green beans and cucumber and gherkins. In India also among these nine vegetables potato ranks first in area and production (Table-1). About 25000000 tonnes of potatoes are produced in India from about 1341000 ha area.

Poland, China, USA, India, Germany, Romania, Netherlands, UK, France, Spain, Turkey, Italy, Yugoslavia are major potato producing countries. The production of potato in the world and major countries are given in Table-2.

Almost all states grow potato. About 90% of the total potato area is confined to subtropical plains, 6% in the hills and 4% in the plateau region of peninsular India. Statewise area, production and productivity of potato during 1999-2000 to 2002-03 are given in Table-2.

In India present level of production is established to be around 265 lakh MT as per statewise area and estimates given in Table-2 as estimated by NHRDF. The projection of potato production for the year 2009-2010 is 31.4 million tonne and by 2020 the production should reach to 40.1 million tonne to meet the per capita requirement of 25.61 kg/year compared to 24.3 kg/year at present. The details on this are given in Table-3.

**Table 1. Area and production of major vegetables & melons during 2001**

| Crop | WORLD Area (ha) | WORLD Production (MT) | WORLD Productivity (tonne/ha) | INDIA Area (ha) | INDIA Production ( MT) | INDIA Productivity (tonne/ha) |
|---|---|---|---|---|---|---|
| POTATOES | 19,306,725 | 304,392,708 | 15.77 | 1,341,000 | 25,000,000 | 18.64 |
| GARLIC | 1,001,795 | 10,133,315 | 10.12 | 120,000 | 500,000 | 4.17 |
| ONION DRY | 2,736,988 | 46,916,047 | 17.14 | 500,000 | 4,900,000 | 9.80 |
| CABBAGE | 2,593,633 | 54,227,913 | 20.91 | 235,000 | 4,250,000 | 18.09 |
| TOMATOES | 3,657,142 | 99,428,786 | 27.19 | 365,000 | 5,500,000 | 15.07 |
| CAULIFLOWER | 833,090 | 14,421,146 | 17.31 | 350,000 | 5,250,000 | 15.00 |
| OKRA | 770,970 | 3,864,826 | 5.01 | 390,000 | 2,500,000 | 6.41 |
| BEANS, GREEN | 686,909 | 4,671,914 | 6.80 | 150,000 | 410,000 | 2.73 |
| PEAS, GREEN | 887,373 | 7,385,083 | 8.32 | 200,000 | 2,000,000 | 10.00 |
| CUCUMBER & GHERKINS | 1,796,335 | 31,215,163 | 17.38 | 17,800 | 117,500 | 6.60 |
| OTHERS | 8,312,694 | 101,399,591 | 12.20 | 2,036,200 | 10,594,000 | 5.20 |
| TOTAL | 42,583,654 | 678,056,492 | 15.92 | 5,705,000 | 61,021,500 | 10.70 |

Almost 85% of the potato crop is raised in the winter season under assured irrigation. This makes it possible to exploit the relatively disease and pest free and sunny environment for maximum production within short period of about 90 days in contrast to the situation in temperate countries where long duration is required mainly in rainfed conditions. Rainy season potato production is also taken in Karnataka, Maharashtra, HP and Uttranchal. There has been ups and down in area and production of potato on account of weather vagaries and market rates.

Among different states of India, according to NHRDF estimates for the year 2000-2001 Uttar Pradesh is the leading state accounting for 37% of the area and 44% of the production with an average yield of 22.50 tonne/ha in potato. The other major potato producing states are West Bengal, Bihar, Punjab and Assam. In India, per hectare yields are highest in West Bengal followed by Uttar Pradesh, Gujarat and Punjab. Yield obtained in India with those obtained in developed countries or even in experimental fields in India show that there is wide gap between the potential yield of the potato in the country and the yield actually obtained by the farmers. The data in Table-4 where area and production of potato year wise have been given from years 1970-71 to 2002-03 show that in general there is steady increasing trend not only in area but also in productivity and production to meet the requirements except during 1997-98 when crop all over the country was affected adversely due to weather conditions.

## MARKETING INCLUDING EXPORT

Potato is now pre-dominantly cultivated by small and marginal farmers who have little capacity to absorb the shock of crash in prices and resulting losses. Therefore, it is essential to take prompt measure to provide and assured market and fair returns to the growers for further development as also to sustain the level of production. The price support policy is some time adopted in state like HP, UP, Punjab in order to provide some financial relief to potato growers due to sudden fall in the prices. The policies are on adhoc basis and thus it may be suggested that potato price should be determined on the basis of an amalgum of cost of production relating prices and parity price.

At the National level, support to potato prices were provided only indirectly by influencing the market prices through announcement of withdrawn of export. Although Commission for Agril. Costs and Prices could not introduce any scheme of price support in view of various problems in implementation for modernizing price fluctuation the recommendation supported are, open market purchase by public sector agency, expansion of cold storage capacity in public and cooperative sector and the improvement in rail transportation as well as market intervention scheme by state cooperative agencies. The suggestion is also made to find out the feasibility of setting up of processing plants particularly in the public sector if economically viable. The policy of market intervention is continued for potatoes and cold storages are being increased in the country particularly under cooperative sector. India has the potential of becoming a major exporter of both ware potato and seed potatoes as more than 80% of the crop is grown in the winter when there is no potato crop in the temperate countries. During 1997-1998 India exported the quantity of 20798 MT, however, the exported quantity of potato varied from 1970 MT to 34408 MT annually from 1980-81 to 1997-98 as given in Table-5. The export of potato country wise for the year 1994-95 to 1997-98 are given in Table-5A. It shows that if a long term policy is formulated there is no reason why India should not emerge as a major exporter of potato by the year 2020. There is great potential for export of processed potato also to Middle East countries at competitive prices.

## DEMAND PROJECTION FOR POTATO

The demand projections for potato are given in Table-6 which include requirement for domestic consumption (table purpose), requirement for seed, export, processing as also estimated losses. Many times there has been import of potatoes for meeting requirements particularly for processing as the required varieties are not in large production in India. Same condition production is now started with assured procurement which is expected to reduce / avoid the import. The need is also felt to popularize the suitable varieties for processing industries and introducing the techniques for storage to maintain the quality of processed products.

## THRUST AREAS – ISSUES & STRATEGIES

Since increase in productivity of potato is a must for reducing cost of production and increasing availability to meet domestic and export requirement and for increasing income of farmers so also for helping in increased rural employment, it is necessary to identify the thrust areas of development and prioritize the same for effective achievement of the goal at a faster rate.

The future thrusts on potato research and development should be to continue the increase in production and productivity through sustainable and eco-friendly technologies and genotypes.

## Table 2. Estimates of area, production and productivity of potato

| STATES | AREA ('000 Ha) | | | | PRODUCTION ('000 MT) | | | | PRODUCTIVITY (MT/Ha) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1999-00 | 2000-01 | 2001-02 | 2002-03 | 1999-00 | 2000-01 | 2001-02 | 2002-03 | 1999-00 | 2000-01 | 2001-02 | 2002-03 |
| ANDHRA PRADESH | 1.70 | | 2.00 | 2.00 | 11.30 | | 20.00 | 20.00 | 6.65 | | 10.00 | 10.00 |
| ARUNACHAL PRADESH | 5.00 | | | | 32.40 | | | | 6.48 | | | |
| ASSAM | 76.70 | 80.50 | 77.00 | 81.00 | 699.70 | 677.30 | 617.00 | 680.00 | 9.12 | 8.41 | 8.01 | 8.40 |
| BIHAR | 183.50 | 148.10 | 180.00 | 175.00 | 1717.90 | 1375.90 | 2250.00 | 2400.00 | 9.36 | 9.29 | 12.50 | 13.71 |
| GUJARAT | 31.30 | 32.80 | 25.60 | 30.00 | 688.70 | 716.10 | 560.00 | 750.00 | 22.00 | 21.83 | 21.88 | 25.00 |
| HARYANA | 16.50 | 16.70 | 18.25 | 18.25 | 260.00 | 257.50 | 285.00 | 325.00 | 15.76 | 15.42 | 15.62 | 17.81 |
| HIMACHAL PRADESH | 10.60 | 12.80 | 16.00 | 12.80 | 140.90 | 155.00 | 225.00 | 180.00 | 13.29 | 12.11 | 14.06 | 14.06 |
| JAMMU & KASHMIR | 2.40 | | 2.10 | 2.10 | 25.70 | | 31.50 | 31.50 | 10.71 | | 15.00 | 15.00 |
| KARNATAKA | 32.30 | 38.20 | 46.75 | 41.00 | 460.00 | 442.70 | 594.42 | 460.57 | 14.24 | 11.59 | 12.71 | 11.23 |
| MADHYA PRADESH | 68.30 | 30.40 | 13.00 | 30.00 | 870.00 | 329.20 | 225.00 | 350.00 | 12.74 | 10.83 | 17.31 | 11.67 |
| MAHARASHTRA | 15.70 | | 11.00 | 10.45 | 71.40 | | 170.00 | 175.00 | 4.55 | | 15.45 | 16.75 |
| MANIPUR | 2.50 | | | | 12.90 | | | | 5.16 | | | |
| MEGHALAYA | 18.30 | 20.00 | | | 143.20 | 181.60 | | | 7.83 | | | |
| MIZORAM | 0.50 | | | | 4.00 | | | | 8.00 | | | |
| NAGALAND | 4.40 | | | | 46.80 | | | | 10.64 | | | |
| ORISSA | 8.80 | 8.30 | 8.00 | 8.00 | 84.80 | 85.90 | 85.00 | 85.00 | 9.64 | 10.35 | 10.63 | 10.63 |
| PUNJAB | 75.50 | 59.40 | 67.50 | 70.50 | 1563.40 | 1187.10 | 1250.00 | 1305.00 | 20.71 | 19.98 | 18.52 | 18.51 |
| RAJASTHAN | 4.10 | | 6.50 | 6.50 | 47.20 | | 43.00 | 60.00 | 11.51 | | 6.62 | 9.23 |
| SIKKIM | 3.50 | | | | 16.60 | | | | 4.74 | | | |
| TAMILNADU | 3.80 | 5.60 | 5.60 | 5.50 | 72.20 | 103.30 | 104.00 | 100.00 | 19.00 | 18.45 | 18.57 | 18.18 |
| TRIPURA | 5.60 | 5.50 | | | 100.00 | 96.30 | | | 17.86 | 17.51 | | |
| UTTAR PRADESH | 447.70 | 399.00 | 457.98 | 460.00 | 10109.10 | 8496.90 | 10318.00 | 10025.00 | 22.58 | 21.30 | 22.53 | 21.79 |
| WEST BENGAL | 315.90 | 299.70 | 325.00 | 350.00 | 7482.30 | 7673.10 | 7500.00 | 8500.00 | 23.69 | 25.60 | 23.08 | 24.29 |
| UTTARANCHAL | | | 22.02 | 21.50 | | | 482.00 | 485.00 | | | 21.89 | 22.56 |
| DELHI | 5.40 | | | | 52.70 | | | | 9.76 | | | |
| OTHERS | | 54.30 | 50.00 | 45.00 | | 364.80 | 550.00 | 600.00 | | 6.72 | 11.00 | 13.33 |
| **TOTAL** | **1340.00** | **1211.30** | **1334.30** | **1369.60** | **24713.20** | **22142.70** | **25309.92** | **26532.07** | **18.44** | **18.28** | **18.97** | **19.37** |

Source: D.E & S Krishi Bhawan New Delhi for the years 1999-00 to 2000-01 and NHRDF estimates for the years 2001-02 & 2002-03

**Table-3 Projections for area, yield, production and per capita producton of the potato for the period up to 2020**

| Year | Population (millions) | Area (million ha) | Yield (t/ha) | Production (million t.) | Per capita production (kg/year) |
|---|---|---|---|---|---|
| 1990-91 | 839 | 0.94 | 16.89 | 15.21 | 18.12 |
| 1995-96 | 923 | 1.14 | 16.93 | 19.24 | 20.84 |
| 1999-2000 | 1017 | 1.40 | 18.00 | 24.71 | 24.30 |
| 2009-2010 | 1263 | 1.70 | 21.00 | 31.40 | 24.86 |
| 2019-2020 | 1566 | 2.00 | 24.50 | 40.10 | 25.61 |

Production of utilization of potatoes particularly in processed form and marketing potatoes as a major export commodity should also be looked into.

Some of the strategies likely to be adopted are as below:

1. Area expansion of potato by involving the potato as an inter crop in compatible crop like sugarcane.
2. Exploit the potential of *kharif* crop by developing suitable production technology and disease control methods.
3. Saturate traditional potato growing area with high yielding improved varieties.
4. Expand potato cultivation to non-traditional areas through use of high thermo period and resistance varieties.
5. Develop varieties having durable resistance to diseases and pests and capable of giving high yields with relatives low levels of inputs and involve eco-friendly agro technology.
6. Increase availability of healthy planting material in potato growing areas deficit in good quality seeds.
7. Reduce post harvest losses by developing appropriate storage and processing technologies and suitable varieties.
8. Promote action involvement of CPRI in developmental decision like distribution of seed and arranging its further multiplication as bulk input as also true potato seed production.
9. More production of planting material through organized sector and distribution at reasonable rates to growers.
10. Developing disease forecasting system and alarming the farmers for appropriate plant protection.
11. Promote cultivation of exportable varieties and suitable for processing.
12. Develop export market for ware potato, seed potato as well as processed potato products.

Table 4 : area, production and productivity of potato in india (1970-71 to 2002-03)

| YEAR | AREA (million ha) | PRODUCTION (Million tonne) | PRODUCTIVITY (tonne/ha) |
|---|---|---|---|
| 1970-71 | 0.48 | 4.81 | 9.98 |
| 1971-72 | 0.49 | 4.83 | 9.81 |
| 1972-73 | 0.51 | 4.45 | 8.82 |
| 1973-74 | 0.54 | 4.86 | 8.95 |
| 1974-75 | 0.59 | 6.23 | 10.60 |
| 1975-76 | 0.62 | 7.31 | 11.74 |
| 1976-77 | 0.62 | 7.17 | 11.57 |
| 1977-78 | 0.67 | 8.14 | 12.23 |
| 1978-79 | 0.81 | 10.13 | 12.56 |
| 1979-80 | 0.69 | 8.33 | 12.15 |
| 1980-81 | 0.73 | 9.67 | 13.26 |
| 1981-82 | 0.76 | 9.91 | 13.00 |
| 1982-83 | 0.74 | 9.96 | 13.55 |
| 1983-84 | 0.79 | 12.15 | 15.30 |
| 1984-85 | 0.85 | 12.57 | 14.81 |
| 1985-86 | 0.84 | 10.42 | 12.36 |
| 1986-87 | 0.83 | 12.74 | 15.32 |
| 1987-88 | 0.89 | 14.05 | 15.87 |
| 1988-89 | 0.93 | 14.86 | 15.93 |
| 1989-90 | 0.94 | 14.77 | 15.71 |
| 1990-91 | 0.94 | 15.21 | 16.25 |
| 1991-92 | 1.03 | 16.39 | 15.90 |
| 1992-93 | 1.05 | 15.23 | 14.46 |
| 1993-94 | 1.05 | 17.39 | 16.61 |
| 1994-95 | 1.07 | 17.40 | 16.27 |
| 1995-96 | 1.11 | 18.84 | 16.99 |
| 1996-97 | 1.25 | 24.22 | 19.39 |
| 1997-98 | 1.21 | 17.65 | 14.60 |
| 1998-99 | 1.32 | 23.61 | 17.88 |
| 1999-00 | 1.34 | 24.71 | 18.44 |
| 2000-01 | 1.21 | 22.14 | 18.28 |
| 2001-02* | 1.33 | 25.31 | 18.97 |
| 2002-03* | 1.37 | 26.53 | 19.37 |

Source:- Directorate of Economics & Statistics) Krishi Bhavan, New Delhi
* NHRDF Estimates

Table 5. Potato export

| YEAR | QUANTITY IN MT |
|---|---|
| 1980-81 | 7219 |
| 1985-86 | 1970 |
| 1986-87 | 2041 |
| 1987-88 | 3166 |
| 1988-89 | 2983 |
| 1989-00 | 3493 |
| 1990-91 | 2496 |
| 1991-92 | 4692 |
| 1992-93 | 5661 |
| 1993-94 | 7093 |
| 1994-95 | 15617 |
| 1995-96 | 34408 |
| 1996-97 | 22747 |
| 1997-98 | 20798 |

(Indian Agri.-1999)

## DEVELOPMENT PROGRAMMES

During 9th Plan integrated approach for the development of potato was taken up with the financial support for seed production, TPS, irrigation source system, plant protection and production and post harvest management. Production of substantial quantity of quality seed materials of released improved varieties of potatoes were taken which has created a real impact in the coverage of high yielding varieties during 9th five year plan period. In addition transfer of technology programmes through field demonstration plots with high yielding varieties and high production technologies were also implemented in the potential growing centres. The financial assistance for breeder seed production to CPRI, for foundation seed production to NSC, SFCI and NHRDF and for certified seed production to NSC and SFCI was given. The financial assistance for TPS production was given to M/s Bejo Sheetal Seeds, Jalna. Apart from these the programmes on adoption of integrated pest management, farmers participatory demonstrations, irrigation source system such as sprinkler, drip irrigation, were taken for potato under the Integrated Development particularly in state of Karnataka, Uttaranchal, UP, Bihar, Jharkhand, MP, Maharashtra, Haryana, Punjab and West Bengal during the year 2001-02 and 2002-03 with financial assistancae @ Rs.1500/- per ha for IPM and Rs. 10000/- per ha for farmers participatory demonstration. The information on potato rates, market arrival and crop condition are being compiled and regularly informed to the Ministry through information centre developed by NHRDF under the Central Sector Scheme. The programmes are being continued during 2003-04 under the CSS for potato in order to

**Table 5A. Country wise export of potato (quantity in metric tonnes and value in Rs. Lakhs)**

| COUNTRY | 1994-95 | | 1995-96 | | 1996-97 | | 1997-98 | |
|---|---|---|---|---|---|---|---|---|
| | Q | V | Q | V | Q | V | Q | V |
| Kuwait | 244 | 14.91 | - | - | - | - | - | - |
| Malaysia | 505 | 28.48 | 135 | 5.07 | 155 | 12.34 | 18 | 1.12 |
| Maldiv | 499 | 33.04 | 228 | 20.79 | 391 | 20.70 | 122 | 7.56 |
| Mauritius | 2995 | 157.87 | 3223 | 189.14 | 1820 | 145.76 | 300 | 20.86 |
| Nepal | 5055 | 115.67 | 6230 | 153.99 | 3409 | 102.50 | 5214 | 109.91 |
| Pakistan | - | - | 1498 | 94.14 | - | - | 320 | 14.51 |
| Russia | - | - | 7000 | 425.13 | - | - | - | - |
| Saudi Arab | - | - | - | - | - | - | 76 | 4.65 |
| Seychelles | 50 | 2.69 | 161 | 11.49 | - | - | - | - |
| Singapore | 1020 | 530.98 | 348 | 21 | 217 | 18.37 | 99 | 5.83 |
| Srilanka | 2605 | 138.98 | 7250 | 494.24 | 12131 | 996.54 | 12876 | 615.60 |
| Turkey | - | - | 3701 | 213.83 | 2090 | 115.01 | - | - |
| UAE | 2644 | 117.86 | 4634 | 254.74 | 2534 | 168.94 | 1773 | 121.87 |
| Total | 15617 | 1140.48 | 34408 | 1883.56 | 22747 | 1580.16 | 20798 | 901.91 |

(Indian Agri. 1999

**Table-6 projection of potato production, its consumption and surplus/deficit upto year 2010**

| Year | Production | Population of country (lakhs MT) | Consumption person/day (Crore) | Population consume (g) | Requirement for (%) (lakhs MT) | Requirement for seed consumption (lakhs MT) | Requirement for export production (lakhs MT) | Requirement for dehydration (lakhs MT) | Total requirement after Ind. 15% losses (lakhs MT) | Import considering (lakhs MT) | Surplus/ Deficit (lakhs MT)* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1996-1997 | 242.20 | 93.84 | 60.00 | 75.00 | 154.12 | 6.00 | 0.25 | 0.75 | 197.45 | 0.00773 | 44.74567 |
| 1997-1998 | 176.50 | 95.53 | 60.00 | 75.00 | 156.90 | 6.00 | 0.21 | 0.75 | 190.34 | 0.02926 | -13.83598 |
| 1998-1999 | 224.90 | 97.25 | 65.00 | 80.00 | 184.58 | 6.00 | 0.08 | 0.85 | 225.24 | 0.00613 | -0.33986 |
| 1999-2000 | 247.13 | 99.00 | 65.00 | 80.00 | 187.90 | 6.00 | 0.28 | 0.94 | 232.19 | 0.00018 | 14.94320 |
| 2000-2001 | 221.43 | 104.28 | 65.00 | 80.00 | 197.92 | 6.06 | 0.23 | 1.03 | 238.44 | 0.00192 | -17.01397 |
| 2001-2002 | 253.10 | 106.16 | 65.00 | 85.00 | 214.08 | 6.40 | 0.08 | 1.13 | 259.66 | | -6.55862 |
| 2004-2005 | 267.11 | 108.07 | 65.00 | 85.00 | 217.93 | 7.36 | 0.50 | 1.24 | 267.11 | | 0.00000 |
| **2009-2010** | **313.66** | **117.97** | **70.00** | **85.00** | **256.20** | **8.47** | **0.58** | **1.37** | **313.66** | | **0.00000** |

* - Import not included

maintain the production level to meet the demands and bring the stabilizing in prices. The new technologies developed by Research Institutes are to be taken to farmers to achieve the targets.

**Developmental programme for potato under Central Sector Scheme on Integrated Development of Vegetable including Root and Tuber crops implemented by NHRDF during 2000-01, 2001-02 and 2002-03**

| Programme, Component | Year | Physical Target (q) | Financial Target (Rs. Lakh) | Agencies |
|---|---|---|---|---|
| Breeder seed production | 2000-01 | 41.25 | 1.25 | CPRI |
| | 2001-02 | 41.50 | 1.25 | CPRI |
| | 2002-03 | 200.00 | 6.00 | CPRI |
| Foundation seed production | 2000-01 | 500.00 | 7.50 | NSC, SFCI & NHRD |
| | 2001-02 | 500.00 | 7.50 | FNSC, SFCI & NHRD |
| | 2002-03 | 700.00 | 10.50 | FNSC, SFCI & NHRDF |
| Certified seed production | 2000-01 | 1000.00 | 10.00 | NSC, SFCI & NHRD |
| | 2001-02 | 1200.00 | 12.00 | FNSC, SFCI & NHRD |
| | 2002-03 | 1250.00 | 12.50 | FNSC, SFCI & NHRDF |
| True Potato seed production | 2000-01 | 1 Pvt. Sector unit | 2 | Bejo Sheetal |
| | 2001-02 | 1 Pvt. Sector unit | 2 | Bejo Sheetal |
| Disease forecasting model | 2000-01 | 1 Unit | 3.75 | CPRI |
| | 2001-02 | 1 Unit | 7.50 | CPRI |

## STRATEGY FOR DEVELOPMENT

Considering the per capita availability, growing trend in consumption of potato in the domestic as well as global markets, the present production of potato is comparatively inadequate to meet the requirement. Based on the domestic demand for consumption as well as industrial requirement for processing and for export including demand for dehydration and seed requirements, the potato production by the year 2010, needs to be increased to the level of 313.66 lakh metric tones from the present level of 253.10 metric tones. The projection of potato production, its consumption and surplus/deficit up to 2010 is given Table-

The strategy for development of potato in the country includes development of agro techniques for non traditional pockets for cultivation of new developed varieties of potato, introduction of export oriented cultivation of potato in suitable Eastern and Northern States at competitive rates for export to adjoining countries and streamlining organic potato production to make available adequate quantity of organic products for export.

The Working Group on Horticultural Development for 10$^{th}$ Five Year Plan has recommended to attain the required production level with an annual increase in production to the tune to 10% by implementing suitable development programmes in a phased manner.

# Importance of potato in food security and poverty alleviation in india

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The potential of potato (*Solanum tuberosum* L) as one of the most efficient food crops is an accepted fact. It is capable of producing high quality protein and over twice as much dry matter and calories per unit area and time as wheat and rice. The biological value of potato protein (73) is better than maize (54) and wheat (53) and is comparable to cow's milk (75). Potato has a great importance in food security especially in view of ever increasing population and shrinking arable land. India's present population (100 crores) is likely to grow at the rate of 1.9%. If the present growth rate is not checked, its population would cross 133 crores by 2025. Surprisingly, every sixth person in the world is an Indian. Moreover, the traditional sources of essential nutrients are dwindling, which have been replaced by high yielding varieties. Potato has, therefore, attained important status in the food basket of the country. It is almost a subsidiary food crop available at cheaper rate than cereals.

Until 1935 the potato defied adoption in sub-tropical plains of India because the varieties planted earlier were from Western Europe and did not express their full yield potential under sub-tropics. Out of 642 commercial varieties introduced from Western Europe only 3 (Great Scot, Up-to-date and President) were commercially adopted. Great Scot and President were grown in Nilgiris and Up-to-Date in both long and short-day conditions of hills as well as plains, respectively.

If one looks at the history of potato cultivation, it can be seen that problems faced by this crop were not only of scientific and technical nature but also of socio-economic and socio-political. It was in 1960s, when the new varieties with varying agronomic characters and high yields were released. Among these, Kufri Jyoti had field resistance to late blight which, however, has broken now partially. It is also immune to wart and has wide adaptability. Its immunity to wart has made it popular in Darjeeling hills, Sikkim, Nepal and Bhutan where wart is a great menace. Kufri Chandramukhi is an early maturing and to some extent tolerant to high temperature at early planting. Kufri Lauvkar is adapted to plateau region. Kufri Sheetman, as its name denotes is tolerant to frost. Kufri Badshah and Kufri Bahar are early bulkers and suitable for main crop. Although these varieties were released in 1960s, yet they occupy larger area than those released later on. Since the release of above mentioned varieties, area and production of potato increased manifolds. After 1960, the increase in area, production and productivity of this crop in India was 4.26 times, 12.4 times and 2.8 times, respectively. Recently CIP B-populations Nos. 420.2, 420.3 and 426.21 which are awaiting their release have been identified in collaboration with CPRI. These possess in-built minor gene resistance to late blight and gave excellent yield without any fungicidal application in the hills. The farmers can thus save about fifteen hundred rupees per hectare on fungicides by growing these genotypes as 5 fungicide sprays are applied to protect existing Kufri Jyoti and other improved varieties from late blight in hills.

Prior to the development of "Seed Plot Technique", seed production was restricted to high hills. Common variety like Up-to-Date had to be adopted in seed programmes of the Indian hills so that the seed of this variety could be available for planting in the month of January (Spring crop) in plains after breaking dormancy of freshly harvested tubers. Since spring crop was fully exposed to aphids (*Myzus persicae*) the seed was degenerated within one season and thus required to be replaced every year by growers in the plains at very high cost. It was in 1965, that "Seed Plot Technique" was perfected at the Central Potato Research Station, Jalandhar making quality seed production a reality in the NW plains under aphid free conditions. Main element of this technique was to plant the crop by middle of October in Punjab, Haryana and Rajasthan; end of October and early November in western UP; and by 15$^{th}$ November in Bihar and Patna when jassids had subsided. Rouging is done as soon as the crop is 20-25 cm high. Adjacent hills should not touch each other so that the contact viruses are not spread by frequent movement in the crop. Haulms are killed in the last week of December or early January before aphids critical number i.e. 100 aphids per hundred compound leaves, is attained. Regeneration is immediately destroyed as aphids like fresh growth. Agronomy of the seed-plot technique was also perfected. Freshly harvested tubers are cold stored so that they are in right physiological condition at the time of planting. The quality seed, thus, produced compared very well with that from the high hills in Himachal Pradesh. Later on it was experimentally found that once the breeders' seed was introduced into the seed system, it remained in its health and yielding ability for 12 years at a place like Modipuram in western UP. Comprehensive production technologies under conditions of small holdings to optimize resource inputs have been developed under AICRP (Potato). Knowledge on economizing irrigation and water harvesting has been generated.

The short duration of the potato is of great importance for inclusion of this crop in multiple and inter-cropping system. Profitable cropping systems were developed under AICRP (Potato) for different agro-climatic regions. Important crop sequences are paddy-potato-wheat, maize-potato-wheat, paddy-potato-potato, etc. Potato has also become an important part of the inter-cropping with sugar-cane and wheat. Significant area is planted with sugarcane in western UP and Maharashtra and potato has great potential as a mixed crop in these areas. Thus, potato can be planted in rotation or as a mixed crop without disturbing area of other crops.

## FUTURE RESEARCH DIRECTIONS

- Breeding for photo-insensitive and heat tolerant varieties with built-in resistance to insect transmitted viruses (PLRV and PVY) and bacterial wilt are called for. It may be impressed that highly heterozygous and heterogeneous populations of wide crosses hold a good future promise. Inter-specific crosses involving tubers forming species of *Solanum* with potential value of characters for adaptation and diseases resistance should be exploited. CIP together with CPRI germplasm collection is a valuable resource and has tremendous potential for exploitation in potato variety improvement programme especially disease resistance.

- Chip making is an important future industry. It has potential for export to Middle East and neighbouring countries. In America about 65% of fresh potatoes are utilized for processing. Similarly, in the Netherlands and UK more than 40-50% fresh produce is processed. Even in Japan and Australia significant quantities are French fried. Processing is also important in stabilizing potato marketing and to avoid frequent potato gluts. Thus this potential needs to be exploited for our conditions. For this it is important that freshly harvested potatoes of processing varieties are made available to the processing industry round the year through contract farming.

- Biotechnolgoy ia a novel tool for directed use of genetic resources, which was not feasible earlier. The potentiality of this technology needs to be exploited particularly for improving quality parameters, nutrition and disease resistance.

- The potential of Breeders seed has not been fully utilized. Generally, the progeny of Breeders seed after one multiplication is disposed of. Multiplication factor is very low. Seed crop management is not up to the mark. It is thus important to develop a functional system of subsequent multiplication of Breeders seed efficiently. It may be stated that in Canada, USA, the Netherlands and UK about 90-95% of the commercial seed by the farmers is officially certified. No uncertified seed is permitted to sell to the farmers. Quality seed thus used by the farmers has greatly enhanced the yields. Likewise, in India too use of only certified seed should be allowed.

- Despite many years of research by CIP in collaboration with CPRI at Patna and Modipuram, TPS technology could not pick up. Right place for TPS is northeastern hills like Nagaland, Tripura and Manipur. So technolgoy should be perfected for this region so that transportation cost of seed tubers from long distances of northern India is economized.

Although potato production in the country has increased several folds, per capita consumption (about 16 kg/year) is much less than many other parts of the world. Potatoes should be eaten as staple food and not as a vegetable. This was also observed by former Union Minister of Agriculture late Sh. Jagjeevan Ram Ji who remarked that a lot of cereals are eaten with potatoes as vegetable. India's potato export had also been around 0.1% of the world export. Notwithstanding the situation on potato utilization and export prevailing so far, there is a great scope and need for increasing domestic consumption and export of table potatoes in European and Gulf countries. Secondly being the only country in south Asia that has its own seed production programme, India has a potential to emerge as a major seed exporter in this part of the world. The potato seed in neighbouring countries is mainly imported from the Europe. The seed produced in India can meet this demand more suitably because of low price and similar agro-climate. This potential for exporting both seed and table potatoes and processed products has hardly been explored. In true sense our country is not yet prepared to absorb excess potato production. It is a high time that diversified utilization and export oriented activities are initiated to tap the potentiality of this crop in national food security and poverty elevation.

# Retrospect and prospect of potato research and development in India

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Potato is not native of India and it was introduced in India from Europe in the beginning of early 17th century. Most of the introduced European varieties either failed to yield well under Indian conditions or degenerated and were lost. The failure of introduced varieties in India was mainly because these varieties were primarily bred to suit temperate long days of Europe, whereas, potato in India is mainly grown during short days of sub-tropical winters. A need was, therefore, felt that potato cultivation in India can not depend on exotic varieties and technologies and the country must have its own research and development program for potato. A scheme for establishment of Central Potato Research Institute was, therefore, drawn up in 1945 under the guidance of Sir Herbort Stewart, the then Agricultural Advisor to the Government of India and CPRI was established in 1949 at Patna. Dr. Srinivasa Ramanujam was the Founder Director (1949-1951 and 1952-1956), who laid scientific foundation for potato research, development for production technologies including seed production and varietal improvement in India.

Hills being the ideal location for producing and maintaining healthy seed and using wide potato genetic base through hybridization for breeding improved varieties, on the recommendations of an expert committee, the headquarters of CPRI was shifted in hills at Shimla in 1956. During the period 1956 to 1983, a chain of regional research stations was established in different potato growing zones of the country to address local problems of potato cultivation. The Indian Council of Agricultural Research (ICAR) started AICRP on potato in 1971 with its headquarters at CPRI, for close linkages with State Agricultural Universities and to evaluate hybrids and potato related agro-techniques developed in the country before they are recommended for commercial use. Together, the CPRI and AICRP account for more than 95% potato related research in this country. As a result of organized potato research on developing indigenous varieties and agro-techniques, the increase in area, production and yield of potato during last 50 years has been almost phenomenal.

Averaged over last three years (1998-99 – 2000-2001), India produced 23.63 million tonnes of potatoes from 1.29 million hectares with an average yield of 18.23 t/ha. Compared to the production figures of 1949-50 (1.54 million tonnes from 0.234 million ha with an average yield of 6.58 t/ha) the increase in area, production and productivity of this crop in India had been 5.5, 15.3 and 2.8 times, respectively. According to last five years averages (1996-97 to 2000-2001) India ranks 4th in area, 3rd in production and 10th in productivity in the world. Although India has made tremendous progress in potato production, the country is not yet prepared to absorb excess potato production. This is mainly due to lack of adequate infrastructure for storage, transport, marketing and utilization of potato. The excess production frequently leads to glut situation making potato production uneconomical. It is high time that we concentrate our efforts for diversification of potato utilization through export, processing and improving domestic consumption.

On export front India's performance had not been commensurate with its global position in potato production. Although India contributes 7.55% to global potato production its share in world fresh potato exports is 0.3% and that for processed potatoes it is 0.2%. In our own continent the country contributes 21% to total potato production but its export share in Asian market had only been 2%. In view of such a scenario, there is a need to evolve strategies export oriented research, export infrastructure and exim policies for promoting potato exports from India. To be competitive in world market we have to reduce the cost of production for which there is need to develop potato varieties and technologies which are economically, technologically, socially and environmentally sustainable.

The quantity of potatoes processed and export of processed potato products from India is very low. Although village level potato processing for home consumption is common in India, large scale processing in organized sector for domestic use and export is a relatively new activity in the country. However, during last few years, processed potato products particularly potato chips are substantially available in the country. With increased demand for such products in urban areas, the potato processing industry in the country has scaled up their production. On processing front, as compared to USA (60%), the Netherlands (47%) and China (22%), less than 1% of total potato production in the country is processed. With globalization in vogue there is fierce competition for exports, demanding development of competence and novel products to remain on the export scene. India can take advantage of large Indian population residing outside in Middle East, South East Asian Countries, Europe, America and Canada by developing potato products with distinct Indian/Oriental taste. Quality of processed potato products is an essential requirement for export. The Bureau of Indian Standards (BIS) has developed certain potato processing quality standards. Processing standards developed in Europe and America are also available in the literature. There is a need to study these standards and pool them together if needed by an expert group to develop a set of quality standards for Indian processors. Such quality standards need to be enforced strictly. There is also need to explore possibilities for putting potato to industrial use mainly starch industry and as an animal feed.

Potato is a staple food in Europe and North America and almost a vegetable in the developing world including India. In India about 73% potatoes are consumed as fresh food in the form of vegetable, 10% as seed, less than 1% is processed, another less than 1% is exported and about 16% goes as waste. Per capita consumption of potatoes in India (about 16 kg/year) is much less than other parts of the world (136 kg/year in Poland) and there is ample room for increasing domestic consumption.

I am sure that with entrepreneurship of Indian farmers & industries, national research capabilities and government support, the days are not far away, when India will be nationally comfortable and globally competitive in potato production, export and utilization.

# The potential and emerging issues of plant biotechnology

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Classical plant breeding is limited to the introduction of required characteristics into plant by genetic crossing during sexual reproduction. This classical approach is useful if the desired genetic improvement is encoded by single gene. If the trait is determined by several genes, it may be extremely difficult to introduce all the genes responsible for crop improvement by using conventional plant breeding techniques. Moreover, we can cross only two sexually compatible plant species. Recent advances in recombinant DNA methodology has given a birth of new techniques called genetic engineering. The genetic engineering is the most recent of a variety of new technologies allowing plant breeders to produce plants with new gene combinations. This has at least two major advantages (i) there is no crossability barrier between donor and the recipient and (ii) there is no co-transfer of unwanted characters thereby reducing the time required to develop new improved varieties.

It is essential that we improve food production per unit land. Genetically modified crops could produce higher yields in countries where soil conditions are poor and population is desperate for food. Crop yields are reduced to considerable low levels because of biotic stresses of pathogens and insect-pests attack. Similarly drought, salinity and temperature are the major abiotic stresses affecting crop productivity. Major network projects should be initiated to usher in transgenic technology to combat biotic and abiotic stresses and to improve the nutritional quality of foods. Concerted efforts must be undertaken to isolate genes and promoters from indigenous crop plants. It is important to increase the gene constructs and promoters which can be expressed in plants for strengthening the transgenic developments. It is important to remember that biotechnology tools complement and extend the traditional methods used to enhance agricultural productivity.

Several genetically modified crops have been released for commercial cultivation in the various developed countries. Some of the examples include; improved resistance to herbicide, improved resistance to insect-pests, improved post-harvest characteristics, improved oil quality, manipulation of seed storage proteins, improvement of iron and vitamin A content in rice. The major genetically modified crops which are commercially grown include insect resistant cotton, potato and corn, herbicide resistant soybean, canola and cotton. The multiple benefit of transgenic crops include flexibility in terms of crop management, decreased dependency on insecticides and herbicides, cleaner and high quality grams or end products.

However, there are several constraints and apprehensions regarding genetically modified food crops. These include, toxicity, allergenecity, carcinicity, use of antibiotic resistance genes and nutritional value. In addition, most of the environmental concerns about transgenic crops have derived from the possibilities of gene flow to close relatives creating super weeds or causing gene pollution among other crops. There is a need of thorough risk assessment, of the issue of public concern on safety especially with respect to health and environment. The other equally important issue is the restrictive role of IPR in actually denying access of these technologies to the developing countries. These are some of the important issues which need to be considered at an early stage in the development of transgenic varieties. However, certain amount of risk is inherent in every new technology and a careful risk benefit analysis is necessary for making a balanced decision. Better consumer information is necessary to allow a well informed potential benefit of using transgenic plants as against the continued reliance on chemical insecticide. Whenever and wherever unresolved question arise concerning underived impact of GM crops, science-based evaluations should be used on case-by-case approach to answer them to the best of our ability. There is a need to streamline and harmonize the regulatory requirements for deployment of genetically engineered plants for sustainable crop production. In country like India, there is a greater need to promote and accelerate the efforts in mobilizing the tools of plant biotechnology for improving the productivity of our major field crops. We must ensure that society will continue to benefit from the vital contribution that plant breeding offers, using both conventional and biotechnological tools. This approach, I believe, will be the most cost-effective, environmentally safe and a sustainable tool to ensure global food security in the future.

# Molecular breeding for crop improvement with emphasis on potato

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During the last two decades, new methods involving techniques of molecular biology have been increasingly used for crop improvement programmes. These techniques mainly include production of transgenic crops and the development of DNA-based molecular markers to be used for indirect marker-assisted selection (MAS). Significant progress has been made in both these areas at the international level. For instance, last year, as much as more than 150 million acres of land was under the transgenic crops world-wide, despite the ongoing debate, and despite the protests against the GM (genetically modified) crops in general and GM foods in particular. Although initially the most important traits that were improved in the transgenic crops included resistance against herbicides, insects and viruses, efforts are now being made to produce GM food crops with improved nutritional quality and also crops for molecular farming (for industry). The most important example of nutritionally improved food crop that is likely to become available to the farmers by the year 2005, is the high vitamin A 'golden rice', although food crops enriched with vitamin C, vitamin E and/or fortified with iron should also become available in due course of time. Food crops are also being designed which will have more favourable content and composition of starch, oil, storage proteins, etc. In India also, *Bt*-cotton was grown last year in about 8000 acres of land in Southern India, and the area is likely to increase to at least 100,000 acres this year. Other transgenic crops like hybrid mustard, *Bt*-rice and protato (potato with improved protein), may also be approved for commercial cultivation in India.

Potato is one of the seven transgenic crops that are already being grown commercially, although the area occupied globally by transgenic potato (insect resistant, virus resistant) in 2002 was less than one million hectares (less than 1%). Transgenic potatoes with disease resistance and improved starch are also being grown in China, but only marginally. This situation is likely to change in the next few years, since more transgenic potatoes for additional desirable traits are being regularly produced. For instance, transgenic potatoes with increased biomass were produced in the recent past. In another study, for the first time, a hybrid *Bt cry* gene (not a fusion gene that was used in the past) was used for production of transgenic potatoes that were resistant to both coleopteran and lepidopteran insects (*Plant Biotechnology* J. **1**: 51-57, 2003; *Planta* **21**: 1003-1012, 2003), An individual *cry* gene, due to its specificity, provides resistance against only one of the several groups of insects, e.g. coleoptera, lepidoptera and diptera. In India also, potato with improved protein should become available within the next 2-3 years.

Future of transgenic research in potato seems to be bright. For instance, an important recent study conducted at the University of Wisconsin, leading to the production of blight resistant transgenic potato, involved isolation from a wild species of *Solanum*, a gene for resistance against potato late blight (*Phytophthora infestans*) (Jiang and Helgeson, published in *PNAS* on line, July 14, 2003). Another important recent study involved the identification of a number of genes for protease inhibitors (Kunitz-type) that are expressed in potato tubers (Salamini and his coworkers from Koln, Germany; *MGG*, 2003). These and similar other genes will be used in future for developing potatoes that would be resistant against a number of insects and pathogenic fungi (e.g. *Fusarium moniliforme*).

In the area of MAS also, DNA-based markers have been used for introgression of a variety of some major desirable genes, mainly through backcross breeding programmes, and the method will be increasingly used in future. Pyramiding of genes for resistance against bacterial blight in rice by scientists at PAU, Ludhiana in collaboration with IRRI (Manila) is one of the several examples of successful use of MAS in plant breeding. There is a need for development of markers in potato, which may be used for selection of difficult traits through MAS in future. While biosafety issues are being raised against transgenic crops and are being addressed world over, no such issues are involved with the technology of marker-assisted breeding. However, the difficulties in the finer molecular dissection of quantitative traits, the interactions (Q x Q and Q x E), in which QTLs are generally involved and the cost involved in MAS may not allow its routine use in plant breeding, in the immediate future.

# Integrated pest management: prospects & constraints

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India's Population is one billion and is expected to be around 1.3 billion by the year 2020. More than 69 per cent of the population lives in rural areas, where main occupation is agriculture, which contributes to India's GDP by 24.2 per cent and provides direct employment to 56.7 per cent population. Fourteen per cent of our total exports come from agri-exports. Two-third of the labour force and $3/4^{th}$ personnel of our military and para forces come from rural areas. In global terms, India today has: 16 per cent of human population, 15 per cent of farm animal population, 2 per cent of the geographical area, 1 per cent of rainfall 0.5 per cent of forests and 0.5 per cent of grazing land. Just to meet the food requirements, India will be required to produce an additional 5 million tones of food grains annually. Thus the greatest challenge to our agriculture is to produce adequate food, feed and fiber to meet the growing demands. Concerted efforts must continue to produce more food and other agricultural commodities per unit of available land, water, energy and time. However, in this process of increasing agricultural production, it has to be ensured that there is no damage to the five ecological foundations of agriculture such as: (i) land (ii) water (iii) forests (iv) bio-diversity and (v) the atmosphere, which are essential for sustaining agriculture.

The green revolution, one of the greatest success stories of India with its dramatic impact on food security has been a role model for many developing countries of the world. However, intensive agriculture spread by the green revolution actually led to newer problems. With intensification of agriculture and subsequent increase in genetic uniformity of crops, dense plant population, mono-cropping, higher fertilization and irrigation, inappropriate cropping systems etc., the insect pests and diseases have increased. It has been estimated that the total loss due to insect pests, diseases and weeds is approximately 18 per cent of the total crop production. The monetary value of the total losses due to pests is more than Rs. 60,000 crores annually. The situation exists in spite of use of chemical pesticides (47020 tonnes in 2001-2002). However, it has been realized that the increasing use of a whole range of toxic chemicals deliberately released into the environment is causing widespread concern about their undesirable impacts on human health and the environment. As compared to chemical pesticides, the Integrated Pest Management system is ecologically safe, as it emphasizes on integrated use of pesticides along with non-chemical methods like cultural practices and biological control with definite focus on judicious and need based use or no use of chemical pesticides. The IPM system manifests the main features of sustainability, like economic viability, environmental safety and social acceptability. The National Agricultural Policy (2001) has given special emphasis on IPM: 'Integrated Pest Management and use of biotic agents in order to minimize the indiscriminate and injudicious use of chemical pesticides will be the cardinal principle covering plant protection'.

National Centre of Integrated Pest Management (NCIPM), New Delhi and Project Directorate of Biological Control (PDBC), Bangalore of the Indian Council of Agricultural Research are coordinating the IPM research and development activities in India. The Directorate of Plant Protection, Quarantine and Storage (DPPQ&S), Ministry of Agriculture, Government of India, popularizes adoption of IPM. The central agencies enlist the participation of all the stakeholders in their efforts. The experience has shown that despite development of IPM technology for rainfed cotton, Pusa Basmati rice, pulses, oilseeds, tomato, cabbage, and some other crops including sugarcane, the spread of IPM is rather slow. Presently, IPM covers around 2% of the total cropped area. Major constraints and action points for implementation of IPM programmes are outlined.

# Organic Agriculture: Global status, requirements, regulatory mechanism and future potential

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In recent years, organic agriculture has emerged as a very dynamic alternative farming system in several countries of the world. This has happened as a consequence of the adverse effects of modern agriculture requiring excessive use of inorganic fertilizers, pesticides and chemicals necessary to achieve high yields of various crops. This approach has resulted in change in soil structure, imbalances in soil micro-organism and organic matter, increased salinity, sodicity, affected water holding capacity of soil and brought in health and environmental problems.

Organic agriculture is more feasible in commodities which are consumed fresh and thus is suitable for a wide variety of agriculture/horticulture and plantation crops. Organic agriculture products in the international market include food crops like rice, wheat, maize, a number of fruits, e.g. avocado, banana, pineapple, cashewnut; vegetable; herbs and aromatic plants like vanilla; plantation crops e.g.. coconut, tea, coffee, cocoa and palm oil. According to SOEL-Survey, 2003, the area under organic farming worldwide is estimated at 2.3 m ha, while 46.3% of this area is in Australia and Oceana, 22.6% is in Europe and 20.8% in Latin America. In North America, Asia, Africa, it is only 6.7, 2.6 and 1%, respectively. Australia (10.56 m ha). Argentina (3.2m ha) and Italy (1.2m ha) occupy large areas under organic agriculture. However, a large proportion of this area is pastureland and certified wild habitated plants. The number of certified organic farms has, however, also been steadily growing.

Internationally maximum organic food retail sales took place in Europe and USA estimated at 10,000-11,000 million US $ during 2002. However, these constitute only 1% in Italy, France and Sweden and 3% of total food sales estimates in Denmark. While the markets in some countries have been growing, in others stagnation has started.

The concept of organic farming is being understood variously. To some it simply implies non-application of any chemical inputs, while a balanced approach suggests identifying inputs based on necessity, nature and way of production and their effect on human health and environment. In addition to this, socio-economic and ethical aspects are also required to be kept into consideration. Codex alimentarius and International Federation of Organic Agriculture Movement (IFOAM) emphasize that only such methods have to be used in organic farming which minimize pollution of soil, water and air. Its primary goal is to optimize the health and productivity of soil, plant, animal and people.

Rules and guidelines for organic production of crops have been issued in various countries. Such guidelines were also developed by Department of Commerce, Ministry of Commerce and

Industry, Govt. of India in March, 2000. While, the matter produced on an organic farm is permitted to be recycled, the same when brought from outside is restricted and its use guided by the certifying agency. Similarly, permitted and restricted minerals; products allowed and restricted in fertilizing and soil conditioning and for pest and disease control have also been clearly specified. Further, National Standards for Organic Production (NSOP) have been issued which give information with regard to conversion requirements, choice of crops and varieties, fertilizer policy, pest, disease and weed management, soil and water conservation etc., which are mandatory to be followed in organic agriculture. It also defines the system of certification and accreditation.

IFOAM has accredited 21 agencies for certification of organic produce all over the world, of which three cater to Indian requirements and are located in Germany, Sweden and Netherlands. An Indian organic certification agency Indocert is also approved to Ministry of Commerce, Govt. of India.

The land area under organic cultivation in India is 41,000 ha and the number of organic farms is 5,661. They primarily produce organic products like fruits, vegetables, tea, coffee, spices and honey besides cereals and cotton. Their main markets are European Union where they get a premium of 20-30%. The demand in different markets covers tropical products not produced domestically, off-season fresh fruits and vegetables and products for which there is a temporary or permanent shortage, novelty or specialty products e.g. retailed packed food products and packaged food and beverages.

Organic farming in India is very old. There is, however, inadequate appreciation both among scientists and growers about scientific organic farming and its benefits and no market exists in the country for sale/promotion of organically grown agricultural products. The Government has thus to come forward with a programme to bring systematic awareness of organic agriculture and incentives to help growers to meet the losses during conversion period. It is but natural that in years to come the sale of organic products will get precedence over conventional products. Needs of a large domestic market resulting from increasing health consciousness and adverse effect of chemical residues is also developing and is likely to result in an expanded domestic market of such products.

# Organic farming-prospects and problems

**GS Sekhon**
*38, The Mall, Amritsar – 143 001, Pb.*

Organic farming implies raising crops with organic inputs only. Chemicals sprayed on the plants commonly as insecticides and fungicides tend to deposit harmful residues on leaves, seeds or other edible portions of the plants which enter the food chain with concomitant deleterious effects. Such experiences have led to a move towards organic farming.

## PROSPECTS

Progressive reduction in our dependence on fertilizers is being increasingly considered a desirable goal in our march towards sustainable farming. Fossil fuel is important in synthesis of fertilizer nitrogen and is likely to run short with time. Rock phosphate, the source of fertilizer phosphorus, can also be in short supply, over a little longer time frame. Maximizing the use of well decomposed organic wastes on farms is regarded crucial for reducing the use of fertilizers on farms and for better sanitation in human habitations in rural and urban areas.

Organic manures improve the fertility and productivity of soil. The use of cattle dung, rural and urban composts, crop residues and green manures has been practiced since the beginning of settled agriculture. Much has been learnt since the advent of scientific agriculture on efficient decomposition of farm yard manure, crop residues and other waste material.

Biogas produced from anaerobic digestion of cattle dung and other organic wastes, produces clean fuel for cooking, lighting and running small machines in rural households and simultaneously yields digested slurry, rich in nutrients, useful in organic farming.

There is increasing awareness about the damage that pesticides cause to human health and environment. Owing to the harmful effect of pesticide residues on fruits and vegetables, and lurking danger of their polluting water bodies and aquatic life, there is growing emphasis on integrated pest management in which farmers apply chemical pesticides in smaller amounts and only when they will have the most effect.

Cultural control consisting of crop rotations, destruction of crop residues, deep ploughing to expose vulnerable insect stages, early detection of the incidence of disease or insect pests and timely weeding out of diseased and insect infested plants offer an opportunity to undertake successful organic farming.

Of late, there has been a growing interest in the consumption of organic foods. Health consciousness about food and non- food products is veering prosperous communities, especially in the developed world to change in favour of organic products. Because organically managed farms produce lower yields than conventional chemicals-based farms, health consciousness goals well-to-do consumers to purchase their choice products at premium prices. Meanwhile, advances in technologies for efficient organic management of soil fertility and pests are enabling organic farms to raise their productivity and profitability.

## PROBLEMS

Organic manure to raise successful crops of vegetables, fruits, basmati rice etc., without application of fertilizers and micronutrient carriers, over sizeable adjacent areas is not readily available. Absence of a sufficient supply of cooking fuel, and failure to install community biogas plants in the villages compels the burning of cowdung cakes. Hence, situations where ready supply of sufficient organic manure is available have to be identified and nurtured as pockets of organic farming.

Vegetable and fruit growers are motivated farmers who maximize production for profit and hence use fertilizers and agricultural chemicals. They would have to be persuaded to abjure their use in favour of an incentive price composting will have to be encouraged to maximize the availability of organic manure and for auxiliary benefits.

Organic management of pests and diseases leads to production of crops at a sub-optimal level. Cultural and biological controls together are inferior to a system of integrated pest management. It needs considerable acquisition of skills to detect onset of diseases and insect pests in very early stages to rogue out infested plants and check the spread of pests and diseases, and to capture the insect pests to prevent their spread.

A lot needs to be done to develop and maintain an efficient system of production and marketing of the products of organic farming at a reasonable premium to the growers.

It is necessary to glean into the future, develop a system of market intelligence, identify most suitable areas for encouraging organic farming, organize producers' cooperative marketing societies and establish credible marketing channels for steady flow of organic foods, in accordance with the demand. In order to maximize the productivity of organic farming, it is desirable to strengthen the advisory system for manure and crop production and organic system of pest management. There is need to create appropriate laboratories for certification of organic farms and to educate their farmers to prepare their fields and farms accordingly.

Since many products of organic farming have a short shelf life, and all of them ought to be quality goods, there should be adequate provision for their packaging, storage and transportation and processing of sub-standard products.

# Water situation in the world and its management for food security

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More than 900 million people suffer from hunger and malnutrition in Africa, Asia, Latin America and even in some developed countries. The shortage of water is experienced by about 1.5 billion people in the world and the number is much higher if we think of the good quality drinking water. Fast growing population in the world, more so in under-developed and developing countries, has pressurized the food resource base. In order to put out the fire of hunger, the man has used the water and soil resources indiscriminately without caring for the future generations or even their own future is at stake. There has been deforestation every year in about 11.2 million ha in the world and 2.0 billion ha of land has been degraded globally, with irreversible damage in 0.3 billion ha. Under such a scenario, it may be difficult to ensure sustainable development. The important issue is to promote the conservation and sustainable use of natural resources which allow long term economic growth and enhancement of productive capacity, alongwith being equitable and environmentally acceptable.

Though about 71% of the earth is covered with water only 2.7% of the world's water resources is fresh water. About 75% of the fresh water is fixed as glaciers and ice caps at the poles and not available for use. About 10% of the fresh water exist as ground water up to 800 m depth and 13% between 800-400 m depth. The rest is available in lakes, rivers, atmosphere moisture, soil and vegetation. Though enough fresh water is available for use in the world, its distribution is not uniform in time and space. Virtually all developing countries, even those with adequate water in the aggregate, suffer from debilitating regional and seasonal shortages. Since food productivity is highly dependent on the spatial and seasonal changes in water availability, the food security cannot be ensured for all times unless suitable measures are undertaken to minimize the effect of this natural apathy.

The population of the world is increasing at an annual compound growth rate of 1.586%, and is expected to be 1.18% between 2000 and 2025. The population, which stands at 6185 millions will increase to about 8303 million in the year 2025. The rate of increase in population is expected to be maximum in sub-Saharan Africa followed by Middle East and North Africa and South Asia. Annual compound growth rate of population increase will be 0.60% in Europe, 0.90% in East Asia and the Pacific and 1.23% in North America and Caribbean. The most unfortunate situation is that the maximum increase in population will be in those areas, which have minimum resources to sustain the demographic pressure. A definite population policy is desired to be framed in these countries to halt the unabated increase in the population or otherwise it would not only be difficult to sustain that much population but also it will have far-reaching detrimental effect on the natural resources.

The land for bringing new areas under plough is limited. Only in sub-Saharan Africa and South America, land exists for exploitation. But in Asia, which is already over-populated, there are remote chances of increasing land under cultivation.

The global per capita availability of arable land is diminishing with increase in population and degradation of this resource mainly through human interferences. At present, per capita availability of land is minimum (0.14 ha) in Asia following by 0.25 ha in Africa and 0.29 ha in Europe. However, by 2025, the corresponding values of land availability would decrease to 0.10 ha, 0.10 ha and 0.29 ha, respectively. For production of 40% more food in 2025, over the present level, enormous and concerted efforts would be required. With reduced per capita availability of land, the task appears to be gigantic. The availability of water will also decrease by this period and this resource will remain a major constraint for optimum productivity. Most of the food production needed over the next several generations must be achieved through yield increases on land now under cultivation.

The global food production of all types stood at 4.74 billion tonnes (including foodgrains, fruits, vegetables and animal products) with 2.45 billion tonnes of edible dry matter. About 99% of this was produced on the land and 1% from oceans and inland waters. About 30 crop species provide most of the World's calories and proteins including 8 species of cereals, accounting for about 66% of the world's food supply. The key issue is to feed the ever increasing population of the world under environmentally and economically sustainable conditions. The main impediment to equitable food distribution is poverty and lack of purchasing power. With constant additions to the population, this aspects becoming more severe.

The demand for cereals will grow to about 3.8 billion tonnes by 2025 as the population of the world is expected to reach 8.3 billion mark. With extremely poor chances of bringing additional arable land under plough, the only way-out is to increase the yields per unit of cropped area. For producing this amount of food under pollution free conditions, main thrust will have to be given on the supply of adequate fresh water to the crops for irrigation. There is requirement of sufficient nutrients also but to get optimum response to the application of fertilizers, adequate water supply to the crops is necessary.

The life of mankind as well as flora and fauna depends on the availability of water. It is the basic commodity to meet human needs for agriculture, drinking, energy, industry, sanitation, recreation, navigation, fishery and supporting environmental ecosystem. Food production require heavy amounts of water for optimum crop productivity. Globally, the current demand of water to produce plant food is about 6659 $km^3$ and is expected to eventually rise to more than 10,000 $km^3$ by 2025. To meet the demand for such a huge quantity of good quality water is a challenge before the planners. About 90% of total water requirement will be for agricultural production in the world to feed ever growing population and the rest for other needs.

The future strategies to improve water resources must entail rain water harvesting and its judicious utilization, more in-situ retention of rain water by diversification of crops and enhancing infiltration, re-use of waste water, irrigation scheduling, suitable pricing of water used and better delivery systems which are flexible and reliable including stream flow controls. Creation of surface storages and inclusion of drought tolerance crops and crop varieties in cropping pattern are other means to combat water stress.

# Potato seed production on commercial basis

**KV Iyer**
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**Abstract: By bringing in new technologies, we need to be conscious that all such technologies should be relevant, appropriate and as far as possible blending with the good traditional systems. We at Chambal Agritech are very conscious of this and are constantly training our growers to blend the traditional and new technologies to optimise their productivity. India's potato industry is large and has potential to develop further with ware and seed exports. Customer demands are continually becoming more stringent and this will apply increasingly to the seed sector. As an industry we have to maintain a progressive stance and maximize our systems in order to be well placed in the global economy.**

In India, agriculture is the backbone and livelihood of 70% of our population. Agriculture is also our largest private sector enterprise. It is imperative; therefore, we continue to make progress in this sector, as this will continue to provide a safety net against hunger and poverty.

As the arable land and other resources like water etc. are depleting, we need to produce more food from these limited resources. Potato is a staple food and an important constituent in our daily life. By 2020, we will have to produce around 40 MTs of potato (current approx. 25 MTs), if our per capita consumption is to be increased from the current 18 kg to 25 kg annually by 2020. CPRI has played a pioneering role in accelerating the potato production with the seed plot technique and rapid introduction of new variety. However, the time has come where modern technology in potato seed production needs to be adopted. This technology would encompass the rapid multiplication system using tissue culture, seed cutting, seed grading and handling, storage and other post- harvest technologies etc.

## 1. RAPID MULTIPLICATION SYSTEM

Modern seed production programs worldwide rely on an infusion of laboratory-sourced material (tissue culture material) from which to start field production. This is provided as either plantlets or small tubers and is known as generation zero (GO) seed. Chambal Agritech through its joint venture collaborator Technico has put up a state-of-the-art facility at Manpura, capable of producing 18 million TECHNITUBER™ (GO propagules) each year. This GO are then field multiplied over 2-3 years to obtain the Generation 2 (G2) seed.

The advantages of a rapid system allows,

- Fewer field multiplication and generation and consequently fewer field exposures to disease.

- The ability to quickly ramp up production on preferred varieties.
- The opportunity to flush the seed production program.

## 2. SEED CUTTING

Seed is generally considered too big once it reaches a dimension of 55 millimeters in diameter. Traditionally the Indian growers are reluctant to cut seed because of post cutting losses and a mindset, which describes this practice. There are cost savings for the industry if this practice is changed and confidence in seed cutting encouraged. If 25% of this oversize seed growing can be effectively utilised in growing another crop, then the benefits for the industry are tremendous in terms:

- Industry development programmes must address the issue of maximizing the seed potential by developing and then demonstrating systems that lead to greater seed recovery. Our preliminary work at Chambal Agritech is showing a normal success with pre-storage, cutting of seed potatoes.

## 3. SEED GRADING HANDLING

Traditionally most of the seed grading and handling in India is performed manually. Seed is harvested and then cured in the field in covered piles. Grading occurs by hand from the piles after several weeks. The inherent danger of storing seed in the field is the exposure to loss due to unfavourable weather. If the seed is fit to harvest, it is fit to grade, pack, suberise and store. Excessive handling of seed combined with field storage leads to vigour loss as a result of damage and day degree accumulation. What appears to be a gentle method of seed handling is in fact detrimental to maximizing the potential of the seed because of the previously mentioned accumulations.

System improvements can be introduced that are beneficial to seed quality but still utilize the large labour force. Minimizing the period from haulm death to cold storage will ensure seed vigour enhancement and risks of pre graded crop loss will be mitigated.

## 4. MAXIMIZING THROUGH MONITORING

To maximize seed quality, the production, storage and handling elements need to be closely monitored. For example, there is now greater availability of monitoring equipment that can provide immediate information on crop water usage. Information on nutrient use or deficiencies can be provided in a few days through sap or dry tissue analysis. Plant stresses can now be largely avoided with a better understanding as to what really is happening within the crop.

Sooner or later there will be priority plantings of food crops in India in order to maximise the water resource. Ground water levels are receding, governments will one day have to make difficult decisions on water and ecological concerns. Water resource poor countries are for example growing high yielding crops with 50% less water through drip irrigation.

Cold storage occurs through extremely hot weather and it is very difficult to maintain preferred temperature and air quality within the store due to the testing conditions outside the store. Seed quality and vigour can be lost due to carbon dioxide retention, low relative humidity, high ethylene levels and fluctuating temperatures within the store. In an industry like India's where small tubers are preferred for seed and ware, quality decline due to poor storage is going completely unnoticed.

The new industry of French fry production will be demanding high performing seed of low physiological age that can only be delivered from a very well managed cold store.

# Honest analysis of current status and scope of true potato seed with the role of private seed sector

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Research on production of True Potato Seeds (TPS) was initiated in 19th century at U.K In India, it started after 1949 by CPRI and then at CIP SWA region. Commercially TPS production started at Tripura by Hort. Dept., Govt. of Tripura and as a private company, Micro Plantae Ltd., started TPS production and marketing. In 1997, Bejo Sheetal Seeds Pvt. Ltd. came into this field. In general from 1994-95 to 1997-98 TPS production was in boom. During that period TPS production had taken place in Karnataka, West Bengal, Gujarat, U.P. (Sadabad) and Maharashtra. But from 1998-99 other organizations reduced the production whereas Bejo Sheetal Seeds increased the production of TPS. Distribution of TPS by govt. agencies was good and Hort. Dept., Govt. of Tripura and Agril. Dept. Govt. of West Bengal sold seeds but after 1997-98 distribution rather lowered down, as those programmes were mostly under development project with the aided fund. When the funding ceased automatically the activity decreased, whereas distribution of TPS by private sector gradually increased as they have targeted programmes including sale. Utilization of TPS for Potato production gradually declined due to lack of socio-economic feasibility. Areas for TPS development were identified but methodology for utilization of TPS to grow potato was not simultaneously evaluated.

Moreover, some companies came up with TPS only for selling without any technical back up. However, from 1998-99 after coming in TPS field Bejo Sheetal Seeds Pvt. Ltd. continuously evaluated the utilization of TPS and derived that in our country use of 'seedling tuber' will be more appropriate rather than use of TPS directly for potato production. Case studies were conducted in U.P., A.P. and Maharashtra and it was observed that commercial production of seedling tubers may be possible either by transplanting or direct seeding method and from 2003-04 a programme is going to undertake production of several hundred tons of seedling tubers which in turn will be distributed in 2004-05 at different low yielding areas. Finally, it has been noticed that there is a great scope for export of TPS in developing countries of Africa and Asia.

# Infocrop-potato: A simulation model for growth and yield of Potato

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[3]*Center for Application of Systems Simulation, IARI, New Delhi-110 012*

Potato has established itself as one of the major food crops of India. It is widely grown and consumed throughout the country. Now India is not only self-sufficient but also has surplus potato available for processing and export. The phenomenal growth in cultivation and production of potato has thrown new challenges. Occurrence of frequent gluts of this perishable commodity leads to price crash. Overproduction puts pressure on transport system and need for extra cold storage space. People's growing liking for freshly harvested produce compared to the cold stored potato is another problem drawing attention of potato research workers, policy planners and administrators. Impact of climate change and environmental degradation on performance of the potato crop is another concern of relevance.

These problems can be addressed through accurate pre harvest forecasting of yield, extending the production to new areas and adjusting and diversifying the acreage under potato in different seasons through out the country. However, it requires generation of voluminous information quickly through extensive location specific research. This is difficult through traditional methods and tools of agronomic research on the one hand and will be too costly and time consuming on the other. Therefore, use of alternative tools of system simulation and modelling is the best option for forecasting yield and increasing the efficiency of agronomic research to sustain the growth of potato production and potato based cropping systems in India. Crop simulation models also serve as modern decision support systems tool to test management options aimed at optimizing producing. Needless to say that models would be helpful to the policy planners for evolving effective strategies for production, storage and disposal of potato. Simulation models serve as an effective teaching and extension aid, too.

Central Potato Research Institute, Shimla has developed a crop growth and yield simulation model INFOCROP-POTATO in collaboration with Center for Applications of Systems Simulation (CASS), Indian Agricultural Research Institute, New Delhi.

**Model description**: The crop growth period in the INFOCROP-POTATO has been divided into development stage 0-1 (planting to tuber initiation) and 1-2 (tuber initiation to physiological maturity). The development stage 1 is further subdivided into 0-0.1 (period between planting to emergence). Daily thermal time was calculated by the formula {(Tmax + Tmin)/2-Tbase}.

**Phenological development:** The daily rate of development during each of the phenological development stages is computed as a function of accumulated daily thermal time in response to various climatic, abiotic and biotic stresses through a number of model parameters and empirical interpolation functions. The different interpolation functions developed for potato were effect of depth of planting on emergence, effect of sprout length on emergence, effect of temperature and photoperiod on tuber initiation and effect of nitrogen and water stress on phenological developments.

**Growth and yield:** Growth depends on light interception, radiation use efficiency (RUE), partitioning of dry matter, senescence and crop nitrogen. Close relationship between crop growth rate and RUE from emergence to fairly large part of the crop growth period is established. The model uses a number of model parameters and empirical interpolation functions to simulate the effects of various factors on RUE, as well as dry matter partitioning, root: shoot ratio, leaf growth and senescence, root growth and crop nitrogen. The effect of photosynthesis rate, crop age, temperature, N stress, $CO_2$ concentration, canopy architecture on RUE were incorporated in the model. The dry matter partitioning was derived as a function of development stage.

**Sink Size**: The model provides for an unlimited sink size because tuber number is largely a genetic character in potato and effect of various factors on tuber number and size is still not well understood.

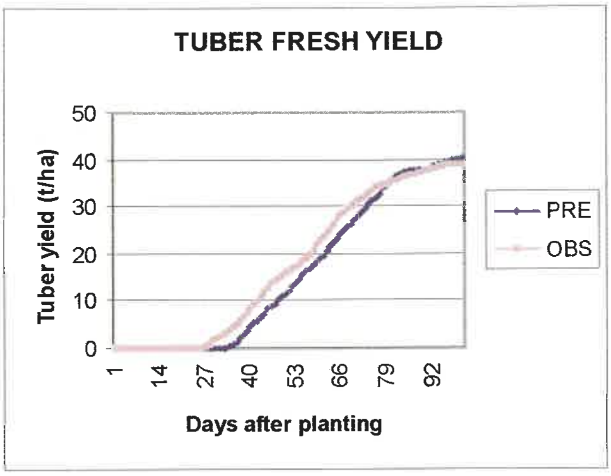
**Parameterization and calibration**: The model interpolation function and governing equations for potato development and growth processes essentially require certain parameters specific to potato crop and cultivars. The model parameters and interpolation functions were calibrated from the data obtained from a field experiment with early, medium and medium to late maturing cultivars grown under potential conditions during autumn 1999 and 2000 at Central Potato Research Station, Jalandhar (31 $^0$N 75 $^0$E), India. Calibration was done by obtaining the best fit curves between the observed and predicted time course data of development stages (emergence, tuber initiation, maturity), growth (total dry matter, LAI, leaf, stem and root wt.) and yield (tuber fresh and dry yield) through iterative procedures.

**Validation**: The model was validated against large historical data set including different locations, short and long day conditions, cultivars and different management environments of water and nitrogen stress. (Marwaha and Sandhu, 2002 and Mehta *et. al.*, 1988). The North-Western plains of Punjab, India offered an opportunity to test the model both under short (autumn) and long (spring) day conditions.

**Model input requirements**: For accurate predictions model needs inputs on daily weather data, soil and management factors. Daily weather data inputs include solar radiation, maximum, minimum temperature and rainfall. Soil data inputs of 3 top layers include depth, organic carbon, sand, silt and clay, ammonical and nitrate nitrogen content. While inputs on management factors include date and depth of planting, seed rate, sprout length of seed tubers, amount and date of fertilizer application, amount and date of irrigation applied.

**Model efficiency**: Model was evaluated by calculating various statistical parameters (Kabat *et. al*, 1995) *viz.* Maximum error (ME), Residual mean square error (RMSE), Coefficient of residual mass (CRM), Model efficiency (EF) and Coefficient of determination ($R^2$) between observed and predicted values for various growth and yield attributes. The model efficiency (EF) for various growth and yield attributes ranged from 0.74 to 0.95 showing the predictions to be highly accurate. The values of the other statistical indicators *viz* ME, RMSE, CRM and $R^2$ were within acceptable limits of error.

**Model capability**: Presently the model is capable of predicting phenological development, biomass and tuber yield on daily basis both under potential and stress of nitrogen and water. It has been found to accurately predict optimum date of planting, emergence, tuber initiation and maturity of potato crop at different locations and seasons. The model predictions of cultivar response for short, early, medium and late maturing cultivars were also close to the known observed responses. The model has been calibrated for 10 most popular Indian potato cultivars. A sample of the prediction of fresh and dry tuber yield is shown in figure 1.



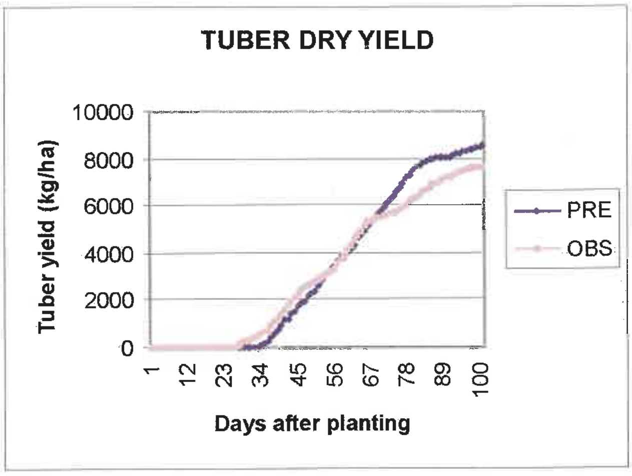




**Fig.1 Predicted growth and yield attributes of cv K. Chandramukhi by INFOCROP-POTATO compared with observed at Jalandhar (1999-2000)**

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# Indian Potato Association – A profile

**KC Sud**
*Secretary, IPA, CPRI, Shimla*

Indian Potato Association was established in 1974 with its Headquarters at Central Potato Research Institute, Shimla (HP). Dr. (Late) Mukhtar Singh, the then Director, Central Potato Research Institute was the guiding force in conceptualizing the idea and giving it a concrete shape. Since then, the Association has been nurtured by many a stalwarts without whom the Association would not have attained the present heights. In the year 1999, the Indian Potato association crossed a milestone by organizing a Global Conference on Potato at New Delhi to celebrate its 25th Year jointly with Central Potato Research Institute, Shimla that also completed its 50th year. It was a memorable year for it as over 500 delegates including 85 foreign delegates shared their experience and ideas on the potato research and technology. The conference was acclaimed as the best organized conference in recent years both by national and international agencies.

## STRUCTURE

The Association has six zones each of which is headed by a Vice-President and councelled by four councilors. President, Secretary, Joint Secretary, and the Treasurer are all elected from the Headquarter (Shimla), for a two-year term. Director General Indian Council of Agricultural Research and Secretary, DARE Government of India is the Chief Patron. The Association also has an Editorial Board headed by an Editor-in-Chief.

## MEMBERSHIP

During the last 29 years, the membership of the Association has grown many folds. At present, it has 740 members of which 642 are Life members. This is the only scientific association in the country where the farmers outnumber the scientists. Cold store owners, processors, and other industrialists are also registered members of the association.

## MANDATE

1. Advance the cause of potato research and development, culture and utilization in a systematic manner and in all its aspect.
2. Provide a common forum and opportunity for personal contact and fellowship among workers in different fields embracing the potato.
3. Hold periodical conferences, symposia, workshops, meetings, seminars, exhibitions and such other gatherings as may be decided upon by the General Body or the Executive Council of the Association from time to time.

4. Making sustained efforts for recognition of the potato as an important food crop of high nutritive value and to conduct publicity/publications and other campaigns through different media for this purpose.
5. Publishing books, reports, summaries of papers and other forms of scientific and technical literature including a newsletter for creating a general consciousness about the potato.
6. Cooperate with other institutions and societies having similar objectives, and fields of activities.
7. Receive grants, subsidies, donations, etc. to achieve the outlined objectives.
8. Promote exchange of scientific and other information and develop other means of communication between those engaged in the potato agriculture and the industry and manufacturers of the processed forms of the potato.
9. To foster regional and international co-operation/collaboration in attainment of the outlined objectives.
10. Organize such other activities that are consistent with and in furtherance of these objectives and those, which are decided upon from.

## ACTIVITIES

1. Publishes a scientific journal viz. **Journal of Indian Potato Association** to promote exchange of scientific information amongst the members.
2. Publishes quarterly "**Newsletter**" which carries news and also articles on new and important technologies developed in the country. It also carries ready to use information for potato growers.
3. Publishes books on potato for dissemination of new information and technology.
4. Organizes both national and international conferences, seminars/symposia, panel discussion, Farmers' Melas etc. from time to time.
5. Confer awards and honours on eminent potato workers, growers, etc.

## IMPORTANT SEMINARS/SYMPOSIA ORGANIZED BY THE ASSOCIATION

1. International Seminar on "**Approaches towards increasing the Potato Production in Developing Countries**" at Central Potato Research Station, Jalandhar (Punjab), November 20-23, 1978
2. Panel discussion on "**Problems of potato cultivation in India**" at Central Potato Research Institute, Shimla, June 13, 1986,.
3. National Seminar on "**Current facets in potato research**" at Central Potato Research Institute (Campus), December 13-15, 1989.

4. National Symposium on "**Strategies for potato production, marketing, storage, processing**" at Indian Agricultural Research Institute, New Delhi, December 21- 23, 1990.
5. National Symposium on "**Potato- Present and Future**" at Central Potato Research Institute (Campus) Modipuram, March 1-3, 1993.
6. Group Discussion on "**Potato based cropping systems**" at Central Potato Research Institute, Shimla during on 30 July, 1994.
7. National Seminar on " **Potato production constraints in low productivity areas**" at Orissa University of Agriculture & Technology, Bhubaneshwar on September 6, 1997.
8. **Global Conference on Potato**, New Delhi, December 6-11,1999.
9. National Symposium on "**Sustainability of Potato Revolution in India**" at Central Potato Research Institute, Shimla on July 31, 2001.

## HONORARY FELLOWS

The Association has so far conferred Honorary Fellowships on 16 distinguished potato workers/growers for their outstanding contributions in the field of potato research and development. They are:

1. Dr S Ramanujam*
2. Dr Pushkarnath*
3. Sh Hari Kishore*
4. Sh IS Dhillon
5. Dr BB Nagaich
6. Dr KL Chadha
7. Dr Kirti Singh
8. Sh SN Bhargava*
9. Dr BP Pal
10. Dr MD Upadhya (Peru)
11. Dr NM Nayar
12. Dr RP Singh (Canada)
13. Dr JG Hawkes (UK)
14. Dr JS Grewal
15. Dr J Horvath (Hungary)
16. Sh LC Sikka
17. Dr Mukhtar Singh*

*deceased.

## DISTINGUISHED FELLOWS

The Association elects distinguished fellows from among its members. So far 25 scientists have been elected as Distinguished Fellows of the Association. They are:

1. Dr SK Bhattacharyya
2. Dr KC Dubey
3. Dr SM Paul Khurana
4. Dr JT Nankar
5. Dr ML Pandita
6. Dr KP Sharma*

7. Dr GS Shekhawat
8. Dr Jagpal Singh*
9. Dr RA Singh
10. Dr RP Singh
11. Dr SC Verma
12. Mr SS Shivalli
13. Dr NM Nayar
14. Dr MS Rana
15. Dr RC Sharma
16. Dr KD Verma
17. Dr PC Gaur
18. Dr UC Sharma
19. Dr SNS Srivastava
20. Dr AK Singh
21. Dr NP Sukumaran
22. Dr GS Kang
23. Dr SS Lal
24. Dr SM Verma
25. Dr BL Barua
26. Dr BP Singh
27. Dr SK Pandey
28. Dr VK Chandla
29. Dr KC Sud
30. Dr KSK Prasad

## AWARDS

The Association has instituted several awards to promote excellence in the field of potato research and development in the country. They are:

1. IPA Medal for the Best Paper published in the Journal of the Indian Potato Association.
2. Best Poster Award.
3. Ramanujam Memorial Award Lecture.
4. Grower of the Year Award.

## PUBLICATIONS

1. Journal of Indian Potato Association – Quarterly.
2. Newsletter: Quarterly.
3. Books/ Proceedings.

## LIST OF BOOKS/PROCEEDINGS

1. **Potato in Developing Countries** Proceedings of International Seminar "Approaches Towards Increasing the Potato Production in Developing Countries" held at Central Potato Research Station, Jalandhar, November 20-23, 1978.
2. **Current Facets in Potato Research** Proceedings of the National Seminar held at Central Potato Research Institute Campus, Modipuram, December 13-15, 1989.

3. **Strategies for Potato Production, Marketing, Storage and Processing** Proceedings of the National Symposium held at Indian Agricultural Research Institute (IARI) New Delhi, December 21-23, 1990.

4. **Potato: Present and Future** Proceedings of the National Symposium held at Central Potato Research Institute Campus, Modipuram March 1-3, 1993.

5. **Summery Proceedings – Global Conference on Potato**

6. **Potato, Global Research & Development Vol. I and II** Proceedings of the Global Conference on Potato, New Delhi, December 6-11, 1999.

## IPA Executive 1974 to 2003

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| 1974<br>1975 | Mukhtar Singh | BS Jogi<br>Kirti Singh<br>Hari Kishore<br>US Kang<br>HN Singh<br>A Kelman | LC Sikka | GS Shekhawat | VM Khanna | BB Nagaich | SC Verma |
| 1976 | BB Nagaich | BS Jogi<br>Kirti Singh<br>US Kang<br>Kirti Singh<br>Niranjan Prakash<br>JS Niederhauser | LC Sikka | GS Shekhawat | VP Malhotra | BB Nagaich | SC Verma |
| 1977 | BB Nagiach | LC Sikka<br>SN Bhargava<br>Daljeet Singh<br>MD Upadhya | JS Grewal | GS Shekhawat | SM Paul Khurana | BB Nagaich | SC Verma |
| 1978 | BB Nagaich | LC Sikka<br>SN Bhargava<br>Daljeet Singh<br>MD Upadhya | JS Grewal | GS Shekhawat | SM Paul Khurana | SB Lal | NP Sukumaran |
| 1979 | SB Lal | MS Rana<br>JS Grewal<br>HS Sangha<br>SN Bhargawa | GS Shekhawat | JS Gill | SM Paul Khurana | BB Nagiach | SP Trehan |
| 1980 | BB Nagaich | BL Barua<br>SL Dubey<br>AK Singh<br>A Naik<br>Guru Amarjit Singh<br>DS Singh | GS Shekhawat | SS Grewal | SM Paul Khurana | KP Sharma | MS Virk |
| 1981<br>1982 | BB Nagaich | JS Grewal,<br>RN Khanna<br>JK Maheshwari<br>M Shyam<br>DS Singh<br>SM Verma | PC Gaur | SK Pandey | SK Bhattacharya | KP Sharma | MS Virk |

| Year | President | Vice President | Secretary | Joint Secretary | Treasurer | Editor-in-Chief | Business Editor |
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| 1984 | | BN Singh<br>MD Upadhya<br>SS Saini<br>CL Khushu<br>SP Singh | Khurana | | | | |
| 1985<br>1986 | JS Grewal | Jagpal Singh<br>BD Sharma<br>OM Bombawala<br>BS Sangar<br>SG Phadtare<br>JT Nankar | SK<br>Bhattacharaya | SS Misra | VK Chandla | SM Paul<br>Khurana | MN Singh |
| 1987<br>1988 | KP Sharma | PC Misra<br>UC Sharma<br>MP Srivastava<br>Nepal Singh<br>Janardan Jee<br>AV Gadewar | RA Singh | RK Birhman | HC Sharma | SK Bhattacharya | BP Singh |
| 1989<br>1990 | JS Grewal | GS Shekhawat<br>Laxman Lal<br>Jagpal Singh<br>SS Saini<br>Janardan Jee<br>KS Krishna Prasad | RA Singh | VK Chandla | MC Sood | SK Bhattacharya | BP Singh |
| 1991<br>1992 | JS Grewal | GS Shekhawat<br>UC Sharma<br>GS Kang<br>Jagpal Singh<br>VS Khushwah<br>RK Arora | VK Chandla | MK Dhingra | SR Yadava | SK Bhattacharya | BP Singh |
| 1993<br>1994<br>1995 | GS Shekhawat | RA Singh<br>UC Sharma<br>GS Kang<br>KD Verma<br>Janardan Jee<br>Gowada P Madappa | SK Pandey | R Chandra | KC Sud | SM Paul<br>Khurana | BP Singh |

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| 1998<br>1999 | GS Shekhawat | PC Gaur<br>BK Sharma<br>IP Chaubey<br>Janardhan Jee<br>PM Govindakrishnan | BP Singh | KC Sud | SR Yadav | SM Paul Khurana | SK Pandey |
| 2000<br>2001 | GS Shekhawat | PS Dahiya<br>SP Trehan<br>SV Singh<br>RP Rai<br>SS Shivalli | PS Naik | KC Sud | SR Yadava | SM Paul Khurana | SK Pandey |
| 2002<br>2003 | SM Paul Khurana | Shiv Kumar<br>Kamla Singh<br>DS Uppal<br>Raj Pal Singh<br>BK De<br>TA Joseph | KC Sud | NK Pandey | JS Minhas | SK Pandey | Brajesh Sigh |

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SILVER JUBILEE YEAR OF NHRDF
2001-2002
1977-2002

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