# An overview of the potato sector in India and prospects of Indo-Dutch cooperation

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In dit vlak wordt door de drukker de foto('s) geplaatst

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October 2011

PPO no. 3250214811

Report commissioned by:

Ministerie van Landbouw, Natuur en Voedselkwaliteit

Project no. 3250214811

Applied Plant Research (Praktijkonderzoek Plant & Omgeving), part of Wageningen UR
Business Unit Arable Farming, Multifunctional Agriculture and Field Production of Vegetables

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# Executive summary

India holds third position in potato area and second position in total potato production in the world. About 90% of the crops are grown in the plains during the cooler autumn, winter and early spring seasons; the remaining is grown in summertime at higher elevations most in the lower Himalayas and some in Karnataka. The average national yield is around 19 tons per hectare; the yield level in better performing states is more than 22 tons per hectare. Potato has the third position in per capita availability of food crops after rice (1) and wheat (2).

About 3% of the national seed requirement originates from the national seed potato multiplication scheme; implying that 97% of the acreage is planted which more or less degenerated seed. Cold storage capacity covers about 50% of the national production, leading to high levels of post-harvest losses after the winter crop harvests. About 1% of the national production is processed into potato chips. The cost of potato production is rather low, this provides great future for processing. India is not exporting its potatoes to other countries.

The Central Potato Research Institute (CPRI) has a monopoly on variety development and seed production. Imports of foreign varieties and seed is banned although processing companies may negotiate exemptions.

Several opportunities for cooperation between Indian and Netherlands companies and institutions were identified. The themes for cooperation are: varietal development; seed production; introduction of Good Agricultural Practices; improving storage, storage management and processing qualities; yield gap analysis and yield increase goals; production of high quality raw material for potato processing factories. It is suggested that the implementation is to be carried out in Public Private Partnerships (PPP).

The purpose of visits and workshop was to create goodwill aimed at removing bans on import of seed potatoes and potato varieties and to initiate collaboration and trade in a number of fields in the potato chain. Opportunities have been identified to strengthen institutional relationships (R&D, seed inspection, GAP) with i.e. CPRI (Shimla), research stations in relevant potato states and the Indian seed potato sector with organisation in The Netherlands: NAK, Plantum, Wageningen UR. Wageningen also discussed the perspective of utilizing DuRPh genes for the Indian potato sector. Collaboration with potato processors and retailers through optimization of yield and reducing post-harvest losses and opportunities for Dutch processors, researchers and manufacturers of cooling and handling equipment were identified. India's neighbours, Bangladesh and Pakistan, have a longstanding bilateral relationship with the Netherlands potato sector through import of varieties and seed potatoes. India's problem with quarantine diseases may affect this relationship and position, as EU does not allow import of Indian potatoes into the EU.

# 1 Foreword

The Agricultural Counsellor of the Netherlands Embassy in Delhi initiated a BOCI project 'Overview of the potato chain in India' in early 2011. A team of Wageningen UR researchers was commissioned to carry out this project. We collected information from reports, personal files, internet and some Dutch companies. We participated in the Netherlands Trade mission to India (5-11 June 2011) and visited the Central Potato Research Institute at Shimla.

Furthermore jointly with the Agricultural Counsellor we organized a potato seminar to present our findings on 5 October 2011 in Delhi. Major potato stakeholders both from India and from The Netherlands attended the seminar; total number of participants was about 60 persons.

This study aims to facilitate the intensification of collaboration between Dutch and Indian stakeholders of the potato chain.

# 2 India ranking second in global potato production volume

China, Russia, India, Poland and U.S.A. contribute a major share to the total world potato production. The potato was introduced into India by the Portuguese sailors during early 17th century and its cultivation was spread to North India by the British. India ranks third contributing around 8% to the world's potato production.

Table 1. **Potato acreage, yield and production volume in India (Source of data: FAO, Rome).**

| **Area Harvested (ha)** | | | | |
|---|---|---|---|---|
| **2001** | **2003** | **2005** | **2007** | **2009** |
| 1,211,300 | 1,337,200 | 1,523,900 | 1,742,800 | 1,828,000 |
| **Yield (tonnes/ha)** | | | | |
| 18,363 | 17,321 | 18,891 | 16,410 | 18,813 |
| **Production (tonnes)** | | | | |
| 22,242,700 | 23,161,400 | 28,787,700 | 28,599,600 | 34,391,000 |

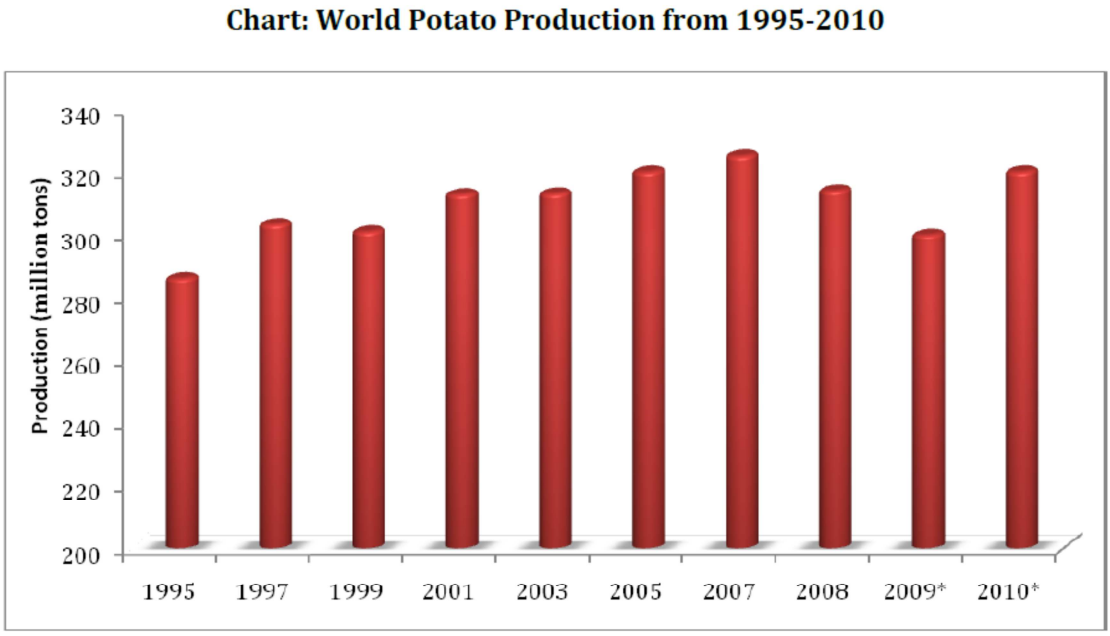
Table 2. **Selected potato data in relation to the Indian potato sector for 2009 (Source of data: FAO, Rome).**

| **Country** | **Acreage (hectares)** |
|---|---|
| China | 5,083,034 |
| Russian Federation | 2,182,400 |
| India | 1,828,000 |
| | **Yield (ton/ha)** |
| United States of America | 46.3 |
| Netherlands | 46.3 |
| Switzerland | 46.1 |
| India | 18.8 |
| | **Production (tons)** |
| China | 73,281,890 |
| India | 34,391,000 |
| Russian Federation | 31,134,000 |

India held third position in acreage in 2009; behind China and the Russian Federation. India ranked second in national production; behind China.

Average yield levels are less than top ranking countries, but such must be put into the right perspective. Indian potatoes are mainly grown during short days conditions leading to short cycle crops implying lower yields levels as compared to crops grown under temperate conditions as in USA and The Netherlands.

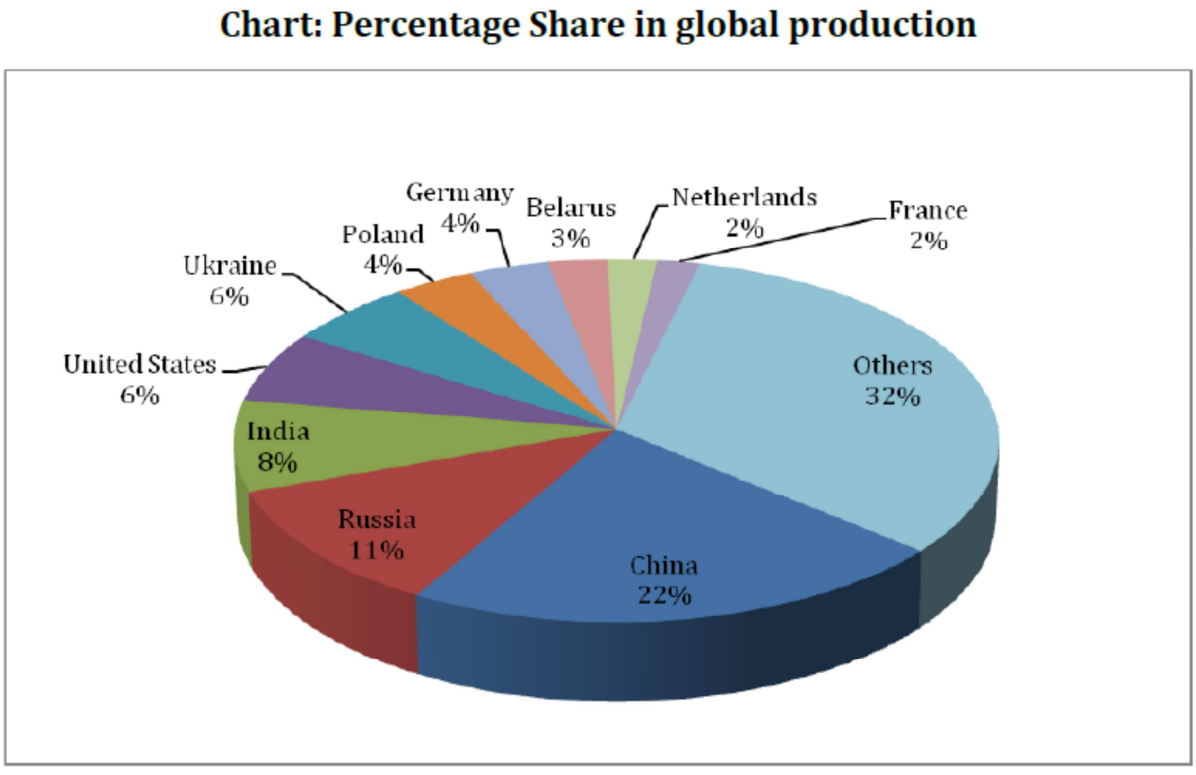
Figure 1. **Average potato production during 1995-2010.**




Source: FAOSTAT (* trade sources)

Production wise India has always remained in the top ten since the last twenty years.
Potato (Solanum tuberosum L.) popularly known as 'The king of vegetables', has emerged as fourth most important food crop in India after rice, wheat and maize.

Figure 2. **National share percentage of global potato production.**




Source: FAOSTAT.

## 2.1 Production regions

Potato is grown almost in all states of India. Major potato growing states are Himachal Pradesh, Punjab, Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra, Karnataka, West Bengal, Bihar and Assam. The Indian potato belt stretches from Punjab (N.W.) to West Bengal in East India.

Uttar Pradesh, West Bengal, Bihar and Punjab together account for about 86% of India's production. Uttar Pradesh is the largest producer of potatoes for India with about 9.821 million tons production in 2004-05 from an area of about 0.44 million hectares.

Figure 3. **90% of the potato crop in India is cultivated as a winter crop in the Indo-Gangetic plain from October until February-March.**

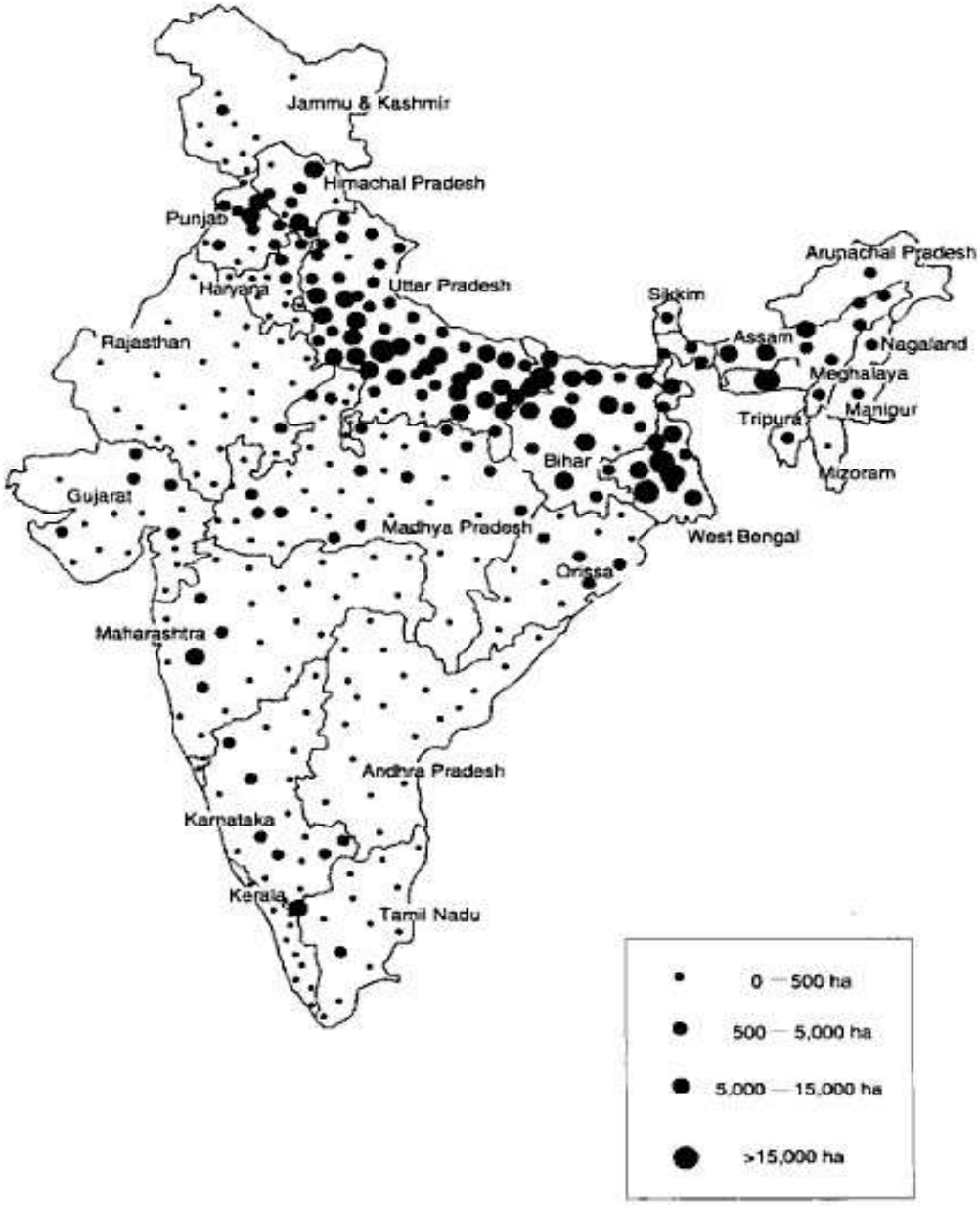


Figure 4. **Major potato states within India.**

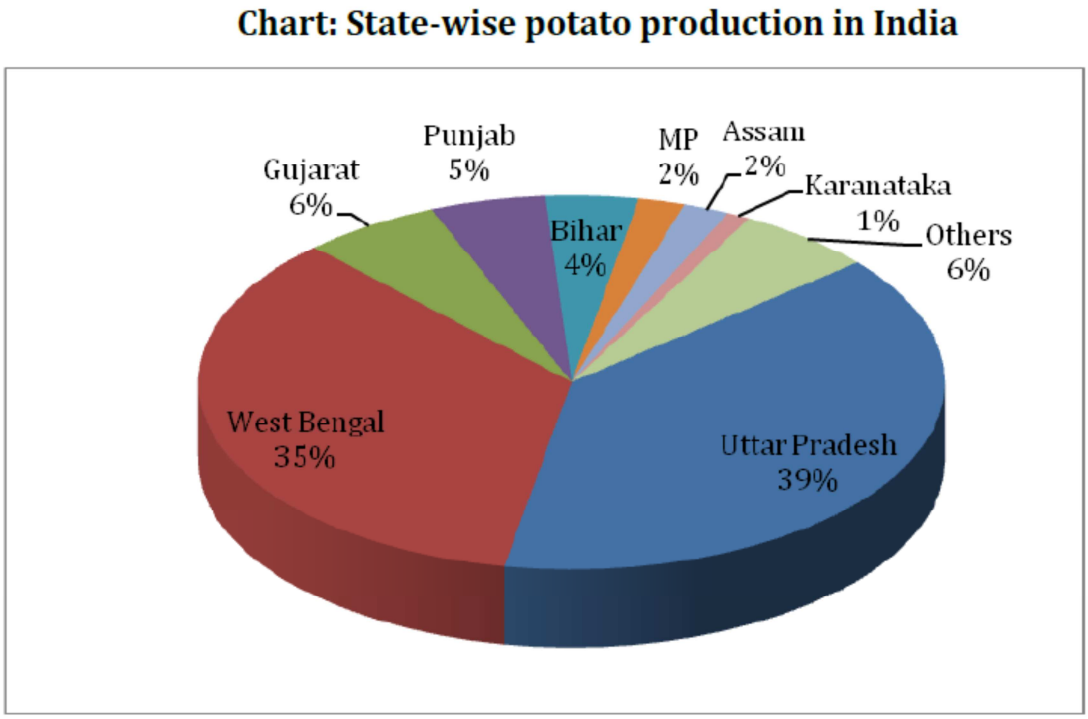



Table 3. **Major production regions.**

| Potato production in major states (2003-2004 & 2004-2005) | | | |
|---|---|---|---|
| Ranking | State | Year and production (in 1,000 tonnes) | |
| | | 2003-2004 | 2004-2005 |
| 1 | Uttar Pradesh | 6,826 | 9,822 |
| 2 | West Bengal | 7,592 | 7,107 |
| 3 | Bihar | 5,657 | 5,657 |
| 4 | Punjab | 1,440 | 1,470 |
| 5 | Gujarat | 780 | 978 |
| 6 | Others | 5,632 | 4,155 |
| | All India | 27,926 | 29,189 |

## 2.2 Yield

The productivity level in India is on average 18 tonnes/ha which is below the world average level of about 29 tons/ha. But it must be considered that India grows its potatoes under short day conditions leading to short cycle crops having lower yields as long cycle crops grown under temperate (long day) conditions. The states according to their productivity levels (in descending order) are placed in the following list:

Table 4. **States ranked on productivity level.**

| State | Tonnes per ha |
|---|---|
| Gujarat | 22.62 |
| Uttar Pradesh | 22.32 |
| Uttaranchal | 21.73 |
| West Bengal | 21.61 |

Production is reported to be as high as 40 tonnes per hectare in Karnataka and Punjab. This must be considered very high as the crop growing period is about 100 days under short day conditions.

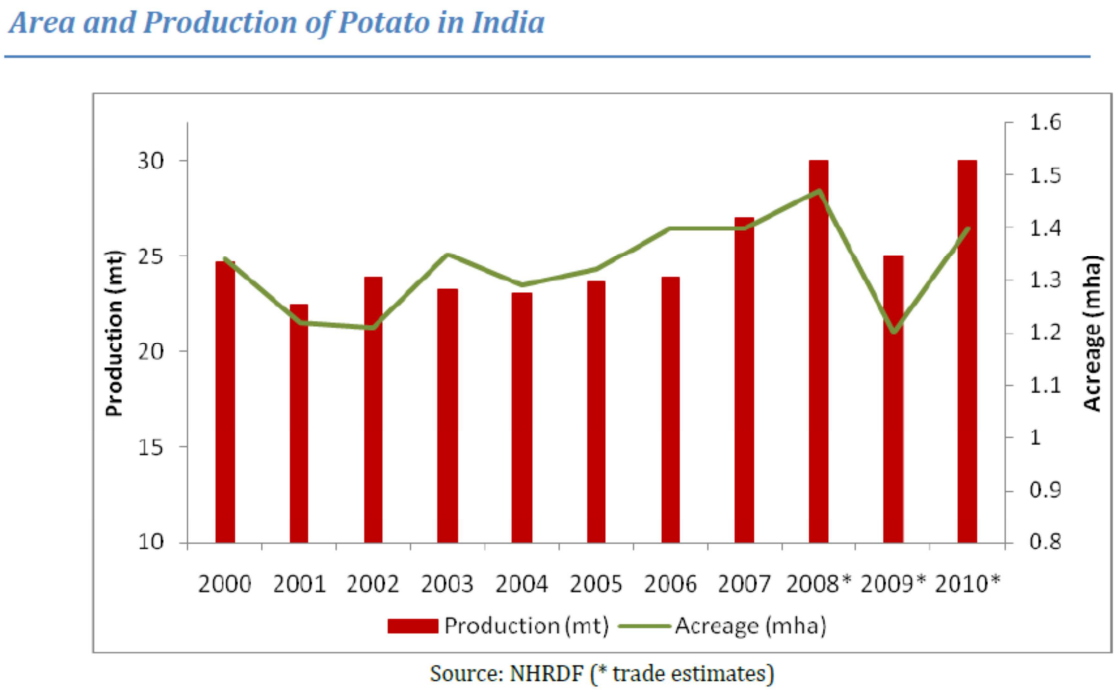
## 2.3 High tech production in Gujurat

The Gujurat based chips producer Balaji has introduced high tech irrigation with their raw material suppliers. Contract farmers received 100% subsidy on investing in drip irrigation, they need to pay back 10% per year over a ten year period.

## 2.4 Production

Production of potato remained almost stagnant around 25 million tonnes in 1999 - 2000. Production declined from 25 million tonnes in 1999-2000 to 24.44 million tonnes in 2000-2001 and 2001- 2002 and increased to 26.5 million tonnes in 2002-2003. Potato production declined again to 24.5 million tonnes in 2003-04. In 2004-05 there is an increase in the production to about 25 million tonnes and a further increase to more than 34 million tonnes in 2008 and 2009 (source of data: FAO). The high production levels in 2008 and 2009 led to a glut situation. It led to a sharp decline in prices, forcing farmers to dump the produce rather than selling it. The transportation cost was higher than what the farmer was getting on sale of the produce. In the absence of support measures, farmers had not brought any new area under potato cultivation during 2009. Hence, the acreage under potato crop went down to nearly 1.2 million hectares last year (2010).

Figure 5. **Pattern of potato acreage and production 2000-2010.**




Source: NHRDF (* trade estimates)

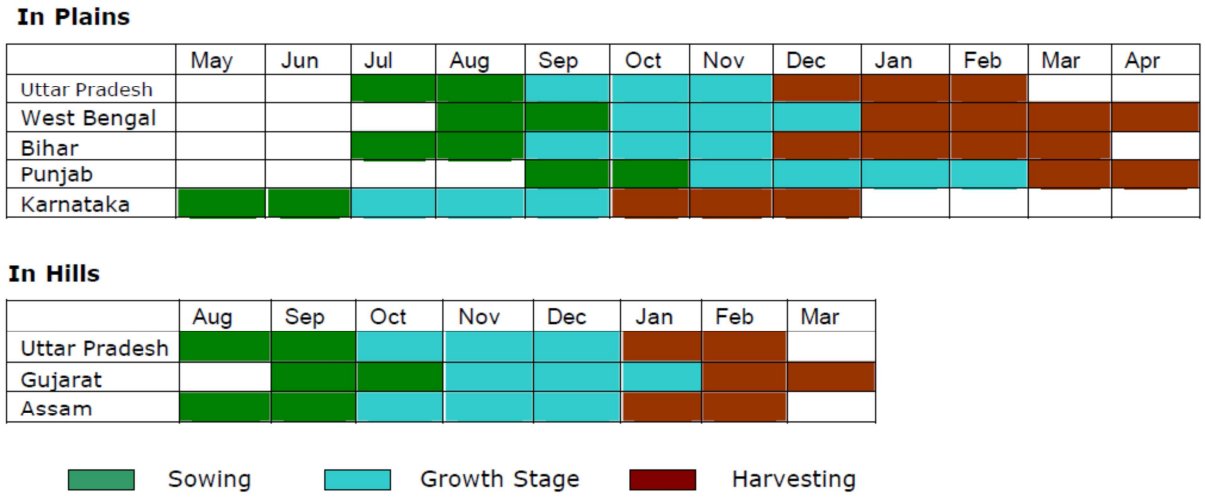
The production increase is a result of larger acreage and better varieties. Generally production of potatoes is about 25 million tonnes which is the normal requirement also for the consumption including requirement for seed potatoes, processing industries, export, waste and storage losses etc.

Even though, India's potato demand was expected to grow by about 15% for the year 2010, while the supplies were expected to surpass demand estimates with an annual growth of about 20% over past year, hinting at lower prices of the agro-commodity in the long-run.
Similarly, for the year 2010, potato production was expected almost to double to around 9.5 million tonnes in West Bengal. The production estimates of potato for Uttar Pradesh were also expected up by 9-10% as compared to previous year, to around 12 million tonnes. The production was also expected more from Punjab, Haryana, Rajasthan, Madhya Pradesh and Andhra Pradesh. The area was expected to be reduced in Gujarat and Maharashtra due to less rain. Overall the area and production in current year is expected to be more as compared to last year (2010).

## 2.5 Production seasons

Potato can successfully be grown in rice based cropping systems. Also, the growth period takes only 80-100 days, hence, it is easy to cultivate and is grown by almost all kinds of farmers.
Potatoes are grown in three seasons: spring crop and autumn crop in the plains and a summer crop in the hills. The autumn season lasts from August / September through December / January, the spring crop is from January / February – April / May. The summer crop season is from March / April till August / September depending on the temperature levels; early planting (and harvesting) in the lower hills and later plantings (and harvesting) in the higher hills.

Figure 6. **Production seasons in various states.**




- In India, more than 80% of the potato crop is grown in the winter season (Rabi) under irrigation during short days from October to March.
- About 10% area lies in the hills during long days from April to October.
- About 8% in the plateau regions of south eastern, central, and peninsular India, is grown as a rainfed crop during the rainy and winter seasons.
- The rainy season (Kharif) potato production is taking place in Karnataka, Maharashtra, Himachal Pradesh, Jammu and Kashmir and Uttaranchal.

Generally farmers grow more than one variety of potato, however small and marginal farmers grow only one variety of potato per season. CPRI suggests quality per climatic conditions and soil texture for each region/ part of the country.

Potato cultivation in the winter season remained a concern as the production had gone down by almost 40% in West Bengal during 2009, due to damage by late blight disease of potato. In this area mist and due cause the foliage to remain wet for prolonged periods during the day making it particularly risky to growt this crop in certain seasons Production hovered around 5.4 million tonnes in 2009 against 9.0 million tonnes in the previous year, over an area of nearly 320,532 hectares.

## 2.6 Production cost

Production cost data were obtained from the Balaji contract growers (June 2011). The production cost per ton is calculated as Euro 0.165, Euro 0.123 and Euro 0.096 per kilogram at yield levels 20, 35 and 50 tons per hectare respectively. Most farmers are likely to have lower yield levels and production cost will be higher.

The most expensive cost items are seed costs and storage costs. Shorter storage periods will result in lower marketing cost.

The Gujurat high yielding farmers producing potatoes at Euro 0.096 per kilogram may be rather competitive with potato growers operating under temperate conditions and be competitive as raw material suppliers to potato processing companies.

Table 5. **Production and long term storage costs in Euro per ha and per ton (calculated for three yield levels).**

| **Item** | **20 ton/ha Euro** | **35 ton/ha Euro** | **50 ton/ha Euro** |
|---|---|---|---|
| Seed potatoes | 748 | 748 | 748 |
| Mineral fertilizer | 243 | 243 | 243 |
| Land rent | 505 | 505 | 505 |
| Agrochemicals | 187 | 187 | 187 |
| Irrigation | 37 | 37 | 37 |
| Harvesting and handling | 561 | 561 | 561 |
| Storage | 1,010 | 2,019 | 2,524 |
| **Total production cost** | **3,291** | **4,301** | **4,805** |
| Yield (tons/ha) | 20 | 35 | 50 |
| **Production cost per ton** | **165** | **123** | **96** |

The Central Potato Research Institute (CPRI) published a profitability analysis of the chips potato variety Kufri Chipsona-1 under Uttar Pradesh conditions ((Potato J. 36 (3-4): 166-172, 2009)): Table 7.

Table 6. **Profitability of processing variety Kufri Chipsona-1 as compared to fresh consumption varieties in Uttar Pradesh.**

| **Costs and prices in Euro** | **Kufri Chipsona-1** | **Other varieties** |
|---|---|---|
| Total variable costs | 891 | 815 |
| Gross income | 2,594 | 2,126 |
| Net income | 1,703 | 1,311 |
| Production cost per ton | 32 | 30 |

Kufri Chipsona-1 yielded a 18% higher price resulting in a higher net return in production. Production costs per kg (Euro 0.032 and 0.030 respectively at 20 tons yield levels) were lower as the Balaji growers as storage costs were not included in the CPRI study.

Figure 7. **Special potato offers in a retail outlet (supermarket) in New Delhi (October 2011).**


The cost of Indian produced potatoes is competitive when compared to the raw material costs in other countries:

Table 7. **Price competitiveness of potato in four countries.**

| Country | Production cost (Euro/ton) |
|---|---|
| India | 30 |
| Netherlands | 140 |
| Philippines | 228 |
| USA (Idaho) | 120 |

The low production cost offers scope for export and for large scale processing both for local consumption and for export (deep frozen French fries).

## 2.7 Consumption

The per capita potato consumption in India has risen from 12 kg/capita/year in the early nineties to over 16 kg/capita in 2007, with a slight decline in recent years (Source: FAO). Potato is the third crop in terms of production and in terms of availability per capita (Table 4). Potato is considered a staple crop, and is used in the following ways:

a) Vegetable : Potato is utilized as major vegetable throughout the country and in preparation of a number of recipes either by using potato alone or by combining it with other vegetables, pulses, cereals etc. This use contributes to more than 85% of the national consumption.
b) Seed : Medium sized tubers are used normally in the northern plains. In the northern and eastern hills, whole tubers are used as seed. Seed is often cut to reduce production costs.
c) Processed products : It is utilized in a variety of ways such as dehydrated potato products like chips, dice, waries, flakes, granules, flour, starch, potato powder and potato biscuits. It is also used to prepare frozen foods like potato patties, puffs, wedges, pancake, dehydrated mashed potatoes etc.

Three types of potato are found in the market:

1. Table potatoes stored at 3 Celsius
2. Sugar free table potatoes stored at 10 Celsius and CIPC fumigated
3. Processing potatoes stored at 10 Celsius and CIPC fumigated

Figure 8. **Potato trading at the Azadpur market in Delhi.**


The processed potato products are classified as follows:

- Fried products : potato chips, frozen French fries, other frozen fries.
- Dehydrated products : dehydrated chips, dices, flakes, granules, flour, starch, potato custard powder soup or gravy thickener and potato biscuits.
- Non-fried products : potato jam, potato *murraba*, potato candy, potato biscuits, potato cakes.
- Canned products

Table 8. **Production of four major crops in India in 2009 (source: FAO).**

| Crop | Production volume 2009 (tons) | Per capita availability 2009 (kg) |
|---|---|---|
| Rice | 133,700,000 | 116 |
| Wheat | 80,680,000 | 70 |
| Potato | 34,391,000 | 30 |
| Maize | 16,680,000 | 15 |

Potato holds third position in terms of per capita availability after rice and wheat.
Consumption of potatoes including table and processed products is expected to increase by 2 – 3% per year as more processed products will be consumed in the years to come. When this pattern will be materialized the Indian potato production volume will double in the next 30 years.

## 2.8 Attainable potato yields

The methodology of calculating attainable yields in the Indian plains requires long term monthly values of minimum and maximum temperatures, solar radiation, precipitation and potential evapotranspiration. Using generic crop parameter values such as temperature dependent sprout growth rate and radiation use efficiency and precipitation deficit during the growing season allows the calculation of attainable yields in a given growing season (planting and harvest date imposed) as well as the amount of water needed for irrigation and the water use efficiency.

The attainable yields (land use efficiency) ranged from 44 (Agra) to 67 t/ha (Allahabad) mainly due to the 20 days longer growing season in Allahabad and the higher solar radiation values than in Agra. The water use efficiency in both areas are similar with 197 kg fresh potato per mm water applied (=per 10 $m^3$ water (= 19.7 g /litre fresh potato matter (about 4 g/litre dry matter)).

The figure below shows the yielding ability in each area and also the water use efficiency. It can be used by policy makers. Where land is scarcer than water the land use efficiency will prevail, where water is scarce the water use efficiency will determine in what to invest.

Table 9. **Attainable yield levels in some potato growing regions in India.**

| **Potato Growing Area** | **Attainable yield =Land use efficiency (t/ha)** | **Water use efficiency (kg/mm)** |
|---|---|---|
| Agra | 44.1 | 197 |
| Ahmedabad | 50.7 | 80 |
| Aligarh | 50.8 | 151 |
| Allahabad | 67.0 | 197 |
| Amritsar* | 14.4 | 43 |
| Barddhaman | 47.9 | 154 |
| Gwalior | 46.7 | 140 |
| Kanpur | 58.6 | 144 |
| Kota | 55.9 | 194 |
| Varanasi | 60.2 | 178 |

The actual yields in the main potato growing areas in India vary between 18 and 24 t/ha which is about a 30 to 50% of attainable. In well-developed potato situations (Western Europe, USA,…) this is usually between half and 2/3 of attainable showing that the present about 40% of attainable can move up to 60% of attainable. This means average yields are expected to move from about 22 t/ha to 32 t/ha in the next decennium provided growers are assisted in decision making and provided the appropriate inputs are available.

Figure 9. **Potato is an important trading commodity in Azadpur market (New Delhi).**


## Latest in potatoes in India (from the newspaper)

It has been reported by the International Food Policy Research Institute (IFPRI) and the International Potato Centre (CIP), that India is likely to have the highest growth rate of potato production and productivity during 1993 to 2020. During the same period, demand for potato is expected to rise by 40% worldwide. This indicates that a picture about a clear opportunity to capture the huge domestic and international market of potato by producing quality potato and its products. According to these growth rates, total potato production in the world in 2020 will be 403.5 million tonnes with China producing about 87.8 million tonnes and India 43.3 million tonnes.

Potato growers in Jalandhar have inked a deal with Russian businessmen to export the tuber. The first consignment is expected to leave Jalandhar on February 17 ( 2011 ) and the total contract size of export is 5,000 tons. This is for the first time India will be exporting potatoes to Russia which is facing a supply shortage. Punjab growers are also in talks with the Arab world for exporting the vegetable to Iran, Iraq and Dubai. West Bengal farmers are looking at opportunities to ship potatoes to countries like Malaysia, Singapore, Sri Lanka and Bangladesh.

Most recent news concern acquired lease on cold storage in Silguri (West Bengal) and has the capacity of 20 tons. Retail prices had shot up to Rs. 22 per kg, forcing the state government to offer subsidies on the staple vegetable, it bought potatoes from cold storages and sold them in 12 retail markets in Kolkata and its suburbs at Rs. 13 per kg. This year ( 2011 ) the situation is opposite. The state government has asked consumer cooperatives under the West Bengal State Consumers Cooperative Federation Ltd (Confed) to procure at least 1 million ton of potatoes from farmers at Rs. 175 per 50 kg bag, or Rs. 3.50 per kg. It has sanctioned Rs. 400 crore (0.67 billion Euro) for the proposed procurement. “When we have a bumper crop like this, we normally sell potatoes in other states such as Bihar, Andhra Pradesh, Chhattisgarh, Jharkhand and Assam,” said Mortaza Hossain, West Bengal’s minister of agricultural marketing. “But even that isn’t possible this year because other potato-growing states such as Uttar Pradesh and Punjab have also had a very good crop.” West Bengal accounts for around one-third of the country’s total potato production, according to Abhirup Sarkar, professor of economics at Kolkata’s Indian Statistical Institute.

Desperate attempts to ensure quality produce: PepsiCo India is expanding in West Bengal and in the next three-four years, the company is looking to bring at least 4,500 acres (1,800 hectares) in the state under contracted cultivation, according to Bhatia. Cold storages in the state have the capacity to preserve only half the quantity produced this year, according to Swapan Mondal, president of the West Bengal Cold Storage Association.

# 3 Diseases and pests

Late blight and viral degeneration of seed stocks are major problems of potato cultivation in India. Late blight is particularly a problem in the spring crop; farmers spray 3-4 times. Disease problems are further aggravated by the incidence of a wide range of other biotic stresses and the emergence of new pathogens and pests. The use of large quantities of pesticides has resulted in problems related to environment, residues, and resistance development in pests. Thus, there is a need to develop eco-friendly disease/pest management practices to boost potato production without compromising on aforesaid issues.
Excessive use of chemical fertilizers and irrigation water has led to the development of degraded soils and environmental degradation in many parts of the country.

Major diseases:
a. Fungal: *Phytophthora infestans* causing late blight (spring crops in north-western plains, north-eastern plains and the central plains) and *Synchytrium endobioticum* causing wart in potatoes is found in the north-eastern hills.
b. Bacterial: *Ralstonia solanacearum causing* bacterial wilt.
c. Tuber and soil borne diseases like *Rhizoctonia solani* causing black scurf and *Streptomyces scabies* resulting in common scab
d. Field and storage: white grubs and potato tuber moth (PTM)
e. Viruses: latent mosaic (PVX and PVS), severe mosaic (PVY), rugose mosaic (PVX + PVY), crinkle mosaic (PVX + PVA), leaf roll (PLRV)
f. Nematode diseases: two potato cyst nematode species *Globobera rostochiensis* and *G. pallida* affect the potato crops in Nilgiri and Kodaikanal hills (southern India) and have been found in Darjeeling. Soil sampling facilities, expertise and protocols are absent.

India has some Quarantine (Q) diseases within its borders:
- *Synchytrium endobioticum* causing wart
- *Ralstonia solanacearum* causing bacterial wilt
- *Globobera rostochiensis* and *G. pallida*

The occurrence of Q diseases limits export to EU.

## 3.1 Control

Late blight is controlled by crop spraying of chemicals. Control of Rhizoctonia requires the application of chemicals either on the seed tuber surface or through soil application (heavy soil infestation).

Synchytrium and Ralstonia are considered as quarantine organisms and should, therefore, be eliminated.

Virus spread must be controlled through growing seed crops in low virus pressure regions and seasons, control of aphids and planting healthy seed potatoes.

Nematode control needs to be conducted through the use of (partially) resistant cultivars. PCN resistant varieties are hardly available in India, although the CPRI published catalogue of Indian potato cultivars (2006) lists two resistant varieties.

## 3.2 Decision Support Systems

The Netherlands developed Nemadecide D(ecision)S(upport)S(ystem) encountered serious interest at CPRI (June 2011). DSS for late blight control are hardly known or applied in India. Large potato processors should be interested to enhance their environment profile and reduce production costs.

## 3.3 Good Agricultural Practices

The use of large quantities of pesticides has resulted in problems related to environment, residues, and resistance development in pests. Thus, there is a need to develop eco-friendly disease/pest management practices to boost potato production according to Good Agricultural Practices (GAP).

Presently GAPs are hardly implemented in India. Major retailer chains whether domestic or international are, not yet, operating in the country. However it is likely that processors (Balaji, ITC, McCain and Pepsico) are working with GAP.

Disease forecasting systems such Decision support systems i.e. for late blight control are known at research (CPRI) level. Soil sampling procedures for PCN analysis are absent.

# 4 Varieties

India has identified 16 desi (i.e. originally local or indigenous) varieties and others, as the major commercial varieties, totalling to 32 varieties. Other introduced varieties that have not achieved commercial rank, have either gone out of production, or have not yet become generally grown. Varieties of special interest to potato growers are 14 in number, all originating from the Central Potato Research Institute (CPRI) at Simla (Himachal Pradesh). CPRI is responsible for the development of potato varieties, viable for various Indian climatic conditions. Many CPRI potato varieties are named after a hill station close to Shimla: Kufri. Some examples:

*Kufri Himsona* is used for cultivation in the Himachal Pradesh Hills; varieties for potato processing for cultivation in the plains, are *Kufri* Chipsona-1, *Kufri* Chipsona-2 and *Kufri* Chipsona-3.
CPRI recently developed new potato variety *Kufri Frysona* (2009); high-yielding varieties like *Kufri* Pushkar for the entire Indo-Gangetic belt, *Kufri* Sadabahar for Uttar Pradesh, *Kufri* Surya for warmer areas like Karnataka and Maharashtra.

The List of varieties of 2006 lists 39 varieties bred by the Central Potato Research Institute (CPRI). This list contains a description of each CPRI released variety; data showing the relative performance are not published in the list.

None of the 31 Indian potato varieties released in the country since 1958 were able to meet the standards for processing when processors became active in India in the nineties of the 20th century. Therefore, there has been a tremendous pressure from the processors to import seed potatoes of potato varieties suitable for processing from Europe and USA. Atlantic (USA released 1968) and Lady Rosetta (Netherlands released 1988) have successfully been grown since their introduction.

Figure 10. **The Central Potato Research Institute is part of the Indian Council for Agricultural Research (ICAR).**


To meet the demand for a variety suitable for processing, a crash programme of breeding was launched at the Central Potato Research Institute in 1990. The Kufri Chipsona-1, 2 and 3 varieties were released from this program. However chips producers prefer Atlantic and Lady Rosetta as raw material; Lady Rosetta is considered to be the best chipping variety. It is widely used by chips producers who are well prepared to pay higher prices for Lady Rosetta raw material as compared to Atlantic and the Kufri chipping varieties.

Seeds of Atlantic and Lady Rosetta are officially not imported at present as the Indian government does not allow import of seed potatoes. The seed import ban is a major constraint in growing large volumes for processing and stimulates the repeated multiplication of once imported seed without considering Plant Breeders' Rights.

Generally farmers grow more than one variety of potato, however small and marginal farmers grow only one variety of potato per season. CPRI suggests quality per climatic conditions and soil texture for each region/ part of the country.

Figure 11. **Varieties recommended for various agro-ecological zones within India.**

| Agro-ecological Zone | Recommended Variety |
|---|---|
| North-Western Plains | Kufri Chandramukhi, Kufri Jawahar, Kufri Kuber, Kufri Alankar, Kufri Badsha, Kufri Dewa, Kufri Pukhraj, Kufri Sheetman, Kufri Sutlej |
| North Eastern Plains | Kufri Ashoka, Kufri Kuber, Kufri Chipsona 1, Kufri Chipsona 2, Kufri Lalima, Kufri Pukhar, Kufri Red, Kufri Sutlej |
| West Central Plains | Kufri Safed, Kufri Sindhuri, Kufri Chandermukhi, Kufri Jawahar, Kufri Kuber, Kufri Chamatkar, Kufri Kisan, Kufri Sindhuri |
| Plateau Region | Kufri Chamatkar, Kufri Jawahar, Kufri Jyotir, Kufri Kuber, Kufri Lauvkar, Kufri Pukhraj |
| North Western Hills | Kufri Giriraj, Kufri Jyoti, Kufri Kundan, Kufri Jeevan, Kufri Kumar |
| North Eastern Hills | Kufri Giriraj, Kufri Jyoti, Kufri Megha, Kufri Khasigaro, Kufri Naveen |
| North Bengal, Sikkim Hills | Kufri Jyoti, Kufri Kanchan, Kufri Sherpa, Kufri Giriraj, |
| and Southern Hills | Kufri Muthu, Kufri Swarna, Kufri Neela, Kufri Neelamani |

Source: National Horticultural Research and Development Foundation, Nasik

## 4.1 Specific CPRI position

The CPRI director once formulated two reasons why India is of special interest to potato breeders. In the first place, the Central Potato Research Institute at Shimla, is one of the major potato breeding stations outside the temperate zone, and secondly, India provides a historic museum of very old varieties. These so called desi (indigenous) varieties, introduced at various dates from the seventeenth century onwards, are, in the main, extinct in the countries from which they were introduced.

Figure 12. **Headquarters of the Central Potato Research Institute (CPR)) at Shimla (HP).**


## 4.2 Plant variety protection (PVP)

UPOV membership has been in debate in the Indian parliament since 2002. There have been discussions about its ill effects to farmer and to traditional production knowledge. The government of India has applied for UPOV membership in 2010. The Indian Plant Breeders Right Act is being studied by UPOV. UPOV has so

far not accepted the Indian Act as the Farm Saved Seed chapter does not comply with UPOV regulations. The process of adapting the Act is expected to require some time before India can be become a member of the UPOV 1978 Convention.

## 4.3 Distinction, Uniformity and Stability (DUS)

Information from India reveals that potato breeders can apply for plant variety protection (Distinction Uniformity and Stability) at the office for Plant Variety Protection (NARC complex, Delhi; www.plantautority.gov.in.). CPRI has been mandated to conduct the DUS tests during two seasons in a multi-location testing program. Prior to the DUS testing, the applying company needs to send in plant tissue material for testing on quarantine organisms. The quarantine testing lasts 12 months. Once the material has been found free of quarantine organisms, the material needs to be multiplied within India to obtain medium sized seed tubers. The tests can be carried out in either one of the 22 states within India or in a lesser number of states. The ultimate registration is per state and depends on the number of states where the tests have been conducted.

Presently two Dutch potato breeding companies are interested in the India potato market: C. Meijer and HZPC. A major worry is the transparency of the Indian variety testing system and the control of seed and ware potato trade within India. The concept of farm saved seed is widely applied within India's large farming community.

During the Dutch – Indian potato seminar (Delhi, 6 July 2011) a representative from the Punjab potato industry stated the large reluctance of Punjab potato growers to pay licences for using seed from protected (foreign) varieties.

The International Potato Center (CIP) claims to have very promising varieties for processing in India. Such varieties are public domain varieties and therefore fitting in the Indian perspective. CIP, CPRI and Pepsico are working together in testing this material for the Indian potato sector.

## 4.4 Value for Cultivation and Use (VCU)

Tests for Value for Cultivation and use (VCU) are not as standardized as in NW European countries. CPRI published its most recent Catalogue of Indian Potato Cultivars in 2006. The catalogue contains a description of CPRI released varieties but has no data detailing characteristics. It appears the transparency of the catalogue is rather absent in terms of data supported performance statements and protocols used both for observations and data processing.

## 4.5 Illegal seed potato multiplication

Potato processing industries in India have been able to negotiate for the import of varieties and seed potatoes specifically for chipping (crisping) purposes: Atlantic and Lady Rosetta. Both varieties, and particularly the latter, are considered to be more suitable as compared to the CPRI developed chipping varieties (Chipsona 1, 2 and 3). Atlantic is a public (USDA developed) variety. On the other hand Lady Rosetta is a variety bred by a private Dutch potato breeding company (C. Meijer). Seed multiplication of Lady Rosetta is conducted in an illegal manner: royalties of license fees are not paid to the owner of the variety: C. Meijer company. Private breeders are facing an unacceptable use of their varieties and are acting very cautiously with respect to bringing their varieties into India as they fear to experience financial losses due to illegal seed multiplication within India.

Private breeders need to have a return on their R&D / breeding investment in order to continue their breeding work in a financially sound way.

# 5 Seed production

The Central Potato Research Institute is responsible for basic seed production. Presently it produces annually about 2,500 tonnes of breeders (basic) seed potatoes and supplies 2,000 tonnes to the state department of agriculture/horticulture. The national seed corporation and state seed corporations multiply breeders seed further to produce foundation seed and certify and provide it to farmers.

## 5.1 Ban on import of varieties and seed

The Indian government does not allow importing seeds nor varieties from abroad. The ban on importing varieties is likely to restrict the development of a multifunctional potato industry in India. The nation is now solely relying on CPRI to produce varieties for all markets: table, French fry, chips (crisps) and flakes. The internationally operating potato breeding and seed selling companies are keen on introducing their varieties in the fast expanding Indian market specifically as these companies have well performing varieties for both table and processing markets. The CPRI varieties Chipsona-1, 2 and 3 released for the chips markets appear to be less successful in comparison with the preferred Atlantic and Lady Rosetta varieties.

It is to be expected that ceasing the import restrictions will lead to an enrichment of potato germplasm in relation to more adequate serving the developing markets within India.

## 5.2 Seed distribution

In many states, the government has a policy of distributing certified seeds at subsidized rates to potato farmers and is, therefore, one of the factors affecting the area and annual production of potatoes.
Usually state departments of horticulture have the responsibility of providing good quality planting material for the farmers. For the potato crop, the department purchases basic seed from the central potato research institute (CPRI), Shimla. The foundation seeds are supplied to progressive farmers to produce certified 1, 2 and 3 if needed. The department of horticulture buys back the certified seed to distribute among the farmers' seed demand.
Major seed producing zone is northwest, states of Punjab and Uttar Pradesh and, to some extent, West Bengal.
The seed produced through the formal system is not able to meet the demand of farmers far away from seed producing zones; zones such as north eastern India. About 3% of the national seed requirement is produced through the official seed system. This implies about 97% of the seed planted by potato growers is of more or less degenerated stock.
In viable states very small quantities of seed are retained out of own farms or obtained from other local farmers.
Small and medium farmers have higher dependence on cooperative societies forgetting quality seed-potato while medium and large farmers purchases more seed from private seed companies than the cooperative societies.
Marginal farmers multiply breeder seed in their fields. Therefore crop health in some regions is satisfactory rather in other suffer great setback.
Poor farmers also tend to grow the varieties which have a lower rate of degeneration than the other varieties.
In far east states and non-seed producing states, the resourceful farmers are able to obtain breeder seeds. This seed is used for 4-5 generations and is replaced with the new seeds when there is substantial decrease in the production. However, marginal farmer in these places have not replaced their seeds in as many as 20 years.

## 5.3 Trends

Quality of seed potato depends to a very large extent on the source of seed. The highest proportion of seed potato is supplied by the cooperative societies after obtaining it from reputed seed potato growers in Punjab.
The development of the "Seed Plot Technique" since the seventies in the 20th century opened up new avenues for potato seed production in Indian tropics and sub-tropics. In addition to Kufri and Fagu in Shimla hills, the CPRI could produce breeders' seed in new areas i.e. at Modipuram (Uttar Pradesh), Jalandhar (Punjab), Patna (Bihar) and Gwalior (Madhya Pradesh). This seed is supplied to the State Departments of Agriculture/Horticulture for further multiplication in three stages: foundation-I, foundation-II, and certified seed. In recent past CPRI had been supplying 2,000 t breeders' seed to these departments annually.

Other important sources of seed were seed companies, market traders (again supplying seed from Punjab and western Uttar Pradesh). A few leading seed producers companies/cooperative societies in India are:

a. Sangha group: Sangha Seeds has R&D tie-ups with three European Potato Seed companies and has a number of visiting scientists and consultants from Europe and the US.
b. YCP: Supply potato to chips industry, supply table potato (for consumption) etc. and also has storage facility for seed and chips potato. Popular clients:
    i. Natraj Foods (LipChip)
    ii. Frito-lay India (Lays Chips)
    iii. Haldiram Snacks & Foods
    iv. Balaji Wafers
c. J.S. farms: Special integrated management and experts for the germination test, genetic purity test, seed health test and grassroot approach for marketing of potato. JS farms supplies potato seed directly to several customers in numerous regions including the Gujrat, West Bengal, Karnataka, Maharastra, Madhya Pradesh, Uttar Pradesh

## 5.4 Conventional seed production

Conventional potato seed production involves production of basic seed (also called breeders' seed) on special seed farms, which are further multiplied by seed agencies and registered seed growers to produce certified seed. Most seed production programs operates a "flush through" system starting each year with fresh true to type and healthy tubers which have been indexed for freedom from viruses. These tubers are further multiplied 4-6 times to reproduce basic seed under strict management practices. Production of certified seed from basic seed requires inspection by certification agencies to ensure the required quality of the seeds being distributed for commercial cultivation. Seed selection by farmers.
Farmers select small size tubers from their bulk produce. A majority of farmer plant the whole tubers. The farmers who do not have enough small tubers cut up the biggers tubers to plant them as seed.

Most sates (19) have state seed certification agencies for the agriculture production and employees from these agencies do the necessary inspection.

### 5.4.1 Foundation 1, Foundation 2 and Certified seeds

Crops under these seed classes are grown at normal spacing during low aphid periods taking adequate precautions to protect it from biotic infection. These seeds classes are subjected to three field inspections by seed certifying agencies during the crop season. In plains the crop is inspected at 30-35, 60-65 and 75-80 days while in the hills at 40-45, 75-80 and 90-95 days. These inspections are carried out as per Indian minimum seeds standards. For assessing post-harvest quality, seed lots are inspected for physical abnormalities or defects, size of tubers, sprouting, occurrence of storage pests and diseases etc. before supply.
The ICAR initiated a self-sustaining "revolving fund scheme for potato breeders' seed production" with the objective of integrating micro-propagation and sensitive virus detection techniques in the initial stages of

potato breeders' seed production.

## 5.5 Seed certification standards

Some of the seed certification standards for potato in India are:

Figure 13. **Permissible limits for purity and diseases in seed potato crops.**

**(A) Permissible limits for purity and diseases in seed crop**

| Class of seed crop | Maximum permissible % of plants showing | | | | | |
|---|---|---|---|---|---|---|
| | Off type | Mild mosaic | Severe mosaic, leaf roll and yellows | Total viruses | Brown rot | Re-growth of plants after haulm cutting |
| FS-I | 0.05 | 1.0 | 0.50 | 1.0 | - | 0.5 |
| FS-II | 0.05 | 2.0 | 0.75 | 2.0 | - | 0.5 |
| CS | 0.10 | 3.0 | 1.00 | 3.0 | 3 plants/ha | 0.5 |

**(B) Permissible limits of damages and diseases in seed tubers**

| Seed class | Maximum permissible % of tubers (by number) showing | | | | |
|---|---|---|---|---|---|
| | Common scab | Black Scurf | Late blight, dry rot, charcoal rot | Wet rot | Total disease |
| FS-I | 3.0 | 5.0 | 1.0 | 0.0 | 5.0 |
| FS-II | 3.0 | 5.0 | 1.0 | 0.0 | 5.0 |
| CS | 5.0 | 5.0 | 1.0 | 0.0 | 5.0 |

**(C) Grade/size standards for seed tubers**

| Seed source | Seed grade | Size in mm | Corresponding tuber weight (g) |
|---|---|---|---|
| Hill seed | Seed | 30-60 | 25-150 |
| | Large | > 60 | > 150 |
| Plains seed | Seed | 30-55 | 25-125 |
| | Large | > 55 | > 125 |

India claims to run the following system: about 930,000 tubers weighing about 70 tons of certified seeds (@ 75 gram per tuber) are produced from one indexed tuber after seven field multiplications. In India potatoes are grown on about 1.39 million hectares and in general farmers replace potato seed stocks one in every 5 years (in certain areas the replacement is after 2-3 years). The certified seed production program would meet about 46% of the country's seed requirement.

Potato growers attending the potato seminar (Delhi, 5 October 2011) expressed their dismay on the current seed production system and the annual volume. About 3% of the total national requirement is originating from the national seed potato scheme. This implies 97% of the potato crops is grown from degenerated seed.
The farmers stated the need to involve more seed growers and foreign seed potato companies and seed certification bodies to get engaged in large scale seed potato production in India.

Most recent there is a development of organically produced seed potatoes.

# 6 Harvest and storage

Harvesting, handling are processes requiring substantial labour; showing that potato production is a labour intensive crop.

Harvesting: Dehaulming [cutting of haulms by sickle or killing by chemicals (e.g. Gramoxone) or destroying by machines] when the crop attains 80-90 days and when the aerial part of the plant turns yellow. Harvesting is carried out by many hands. Manual harvesting, if done properly, results in low damage levels.
Drying/curing: The harvested tubers are dried quickly to remove excess moisture from the surface of tubers for improving their keeping quality in shade, excess exposure to sun is avoided since it turns them green.
Mechanization level: Only large farmers follow mechanized farming, most farmers uses machine drawn ploughs and sickles for ploughing and harvesting. Among the machines used animal/tractor drawn potato digger and different kinds of tractor pulled ploughs are used for preparing the soil and harvesting the produce.

The present state of the harvesting art is using huge numbers of personnel who collect the potatoes by hand, putting the tubers into 50 kg bags and ship the material to a temporarily store or a permanent store. Handpicking of potatoes is a very clean way of harvesting the crop. The future development will lead to increased mechanisation of the actual harvesting and handling. More machinery will be involved leading to higher damage levels. Control and limitation of damage levels will be a challenge when machinery is introduced in the potato chain.
In India, 90% of potatoes are harvested in the northern plains from January-February till the beginning of the hot summer. Seasonal production patterns, inadequate cold storage capacity, low domestic utilization, limited alternative market outlets (e.g., processing and export) often result in market gluts and poor prices at harvest resulting in economic loss to the farmers.

Post-harvest losses are reported to be as high as 40% as the main post-harvest period is the hot summer period. Post-harvest loss control commences through the right control of diseases and pests in the field crops. It is rather common understanding that this control approach may be underestimated.

Total cold storage capacity amounts to about 50% of the total annual potato production. This implies that on average 40-45% of the total production volume is kept under ambient conditions resulting in substantial losses.

The National Horticultural Board has published detailed descriptions of a potato cold store (www.nhb.gov.in).

Figure 14. **The year round potato calendar in India.**

**The Storage Period**

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Main Harvest | Rabi | | Storage | | | | | | Early Harvest | Rabi | |

*Storage Structures:*
*i) Traditional Storage:*

a) In situ storage :
In this system, farmers do not harvest the tubers and allow it to remain in soil. This method is used for short term storage of 2-3 months only in upland and lowland areas of North eastern states. In this storage, the following practices are found as beneficial :

a. Cover the potato beds with grass which provide shade and cooling effect to the potatoes in upland areas.
b. Cover the potato beds with paddy crop which provide shade and cooling effect to the potatoes in lowland areas.

Farmers do so in expectation of getting better prices and at the time of storing shortage or high cost of storages.

b) Heap storage : In this method, potatoes are heaped under the shade of trees, where 6-30 tonnes of potatoes can be stored. The heaps are covered with a layer of available straw material (about 30 cm thickness). This is a popular storage method practiced in U.P., Maharashtra and Karnataka. The following practices are performed in the heap storage system:

- Selection of storage site in places like under the shade of trees, preferably in orchard. Raised sand/soil platform of height of at least 0.2-0.25 m.
- Spray Mancozeb (0.3-0.5% solution) on the soil/sand at storage site which helps in reduction of rotting during storage.
- Removal of cracked, cut, bruised, damaged, green and rotted tubers before storing.
- Use always the polythene sheet for covering the heaps, which protects the heaps from rains.
- Covering the heaped potatoes with 0.3 mt-0.45 m. straw material (wheat, paddy), placing two layers of locally made mat (chatai) in crosswise direction which improves the efficiency of heap storage.
- Loading of potatoes may be done in the morning since the temperature is low in comparison to noon.

c) Pit storage:
This is a traditional method of storage. In this storage system, two types of pits are prepared i.e. katchha and pucca pits. Katchha pit is rectangular in shape measures 4.5 m (length) x 3.6 m (width) x 14 m (depth) whereas a pucca pit is normally circular in shape with a diameter of about 4.2 m. All the pits are covered with 0.3 m thick straw material (wheat, paddy). It is a popular storage method in Madhya Pradesh. An average 25.6 °C of temperature and 66 per cent relative humidity is maintained. However, this practice is declining due to higher losses and inability to assess potato status during the storage period.

d) Wooden storage structure :
In this system, small wooden rooms like stores about 10 ft. heights are built in the field or near residential area. The walls of the store are built by horizontally fixed overlapping wooden planks which help in preventing seepage in store and running off the rain water. The roof of the store is covered with tin sheet and a gap is left between roof and wall for aeration purpose.

e) Storage in rooms :
In this method, farmers used to store potatoes in small rooms built of brick / stones / cement with or without windows at the ground floor of their residence. The potatoes are stored in this storage either in heaps, gunny bags or in bamboo baskets.

f) Storage in baskets :
In North Eastern states, potatoes are stored in bamboo baskets known as “polo” which provides better aeration to the tubers. The baskets are made of different sizes. The smallest size holds 10 -12 kg and the largest size one quintal (100 kg) potatoes. Smaller baskets are suitable for use as they are convenient to

carry to the fields.

g) Storage in layers :
The method is not very common but popular where platforms of bamboo or wooden planks are constructed by the support of the store wall on one side and bamboo on the other side. It provides better space utilization and helps to minimize rotting of potato.

Potatoes stored in the traditional storage systems will have the average day and night temperature; which will be higher than 25 °C during the Indian summer season in the plians.

*ii) Improved Storage :*

a) Storage at low temperature**:**
Low temperature (at 2-4 °C and 8-10 °C) is the most common method for long-term potato storage. The following practices adopted in this type of storage are**:**

i. Seed potatoes are stored at 2-4 °C as no sprouting takes place at this temperature and metabolic process is at its lowest. Besides, low temperature, sweetening is of little importance in case of seed potatoes.
ii. Potatoes for export and processing purposes are stored at 8-10 °C, will not only save a lot of energy but also make the potatoes more suitable for consumption, processing and export.

b) Storage at 10-12 °C : (recently modified storage practice developed by Indian scientists)
i. Processing potatoes and ware potatoes are stored at 10-12 °C and can be treated with CIPC (isopropyl-N-(Chlorophynyl)carbamate) to inhibit sprout growth.
ii. Use refrigerated containers for export of potatoes stored at 10-12 °C with CIPC treatment when the transit time of export is more than 10 days.

*Storage Facilities :*
a) Farmer's storage**:**
Farmers generally use:
* indigenous in-situ storage system i.e. delayed harvesting the tubers and to allow them remaining in the soil
* also the ex-situ system where the farmers store potatoes in pits, baskets, wooden structures or in heaps or layers in room.
b) Private / Co-operative / Public Storage:
In Private / Co-operative / Public Storage sectors, potatoes are stored at low temperature in cold storages situated throughout the country. Most cold stored are privately owned.
The state-wise distributions of Potato cold storage in above sectors are furnished as under.

Figure 15. **State wise distribution of potato cold stores in India.**

| Sl. No. | State / UT | Potato Cold Storage | |
|---|---|---|---|
| | | Number | Capacity in MT. |
| 1. | 2. | 3. | 4. |
| 1. | Andaman & Nicobar Islands (UT) | 00 | 00 |
| 2. | Andhra Pradesh | 00 | 00 |
| 3. | Arunachal Pradesh | 00 | 00 |
| 4. | Assam | 00 | 00 |
| 5. | Bihar | 187 | 699780 |
| 6. | Chandigarh (UT) | 01 | 1000 |
| 7 | Chhatisgarh | 09 | 27575 |
| 8. | Delhi | 00 | 00 |
| 9. | Gujarat* | 164 | 584848 |
| 10. | Goa | 00 | 00 |
| 11. | Haryana | 172 | 225991 |
| 12. | Himachal Pradesh | 05 | 9748 |
| 13. | Jammu & Kashmir | 05 | 11281 |
| 14. | Jharkhand | 06 | 22500 |
| 15. | Kerala* | 00 | 00 |
| 16. | Karnataka | 0003 | 00 |
| 17. | Lakshadweep (UT)* | 00 | 00 |
| 18. | Maharashtra | 04 | 2436 |
| 19. | Madhya Pradesh | 109 | 553257 |
| 20. | Manipur | 00 | 00 |
| 21. | Meghalaya | 00 | 00 |
| 22. | Mizoram | 00 | 00 |
| 23. | Nagaland | 00 | 00 |
| 24. | Orissa | 37 | 123580 |
| 25. | Pondicherry (UT)* | 00 | 00 |
| 26. | Punjab | 344 | 1097609 |
| 27. | Rajasthan | 19 | 65896 |
| 28. | Sikkim | 00 | 00 |
| 29. | Tamilnadu* | 00 | 00 |
| 30. | Tripura | 00 | 00 |
| 31. | U.P and Uttranchal | 1371 | 8163232 |
| 32. | West Bengal | 364 | 4379347 |
| | **TOTAL** | **2800** | **15968080** |

Total cold storage capacity (15,968,080 tons) can accommodate about 50% of the total annul Indian potato production volume. This implies that on average 40-45% of the total production volume is kept under ambient conditions resulting in (and therefore 'explaining' the) substantial post-harvest losses. 71% of the total storage capacity is established in six states (Table 3).

Increase in storage capacity will be a necessity for reducing post-harvest losses and supplying better quality to processing plants and to retailers wishing to sell high quality potatoes in their retail stores.

Increased storage capacity will ultimately lead to lower marketing cost as losses will be reduced substantially.

Cold storage charges (2011) are reported as IRS 10 per 50 kg bag per month.

## 6.1 Store construction

Traditional Indian potato store construction is rather straightforward. Stores are insulated brick buildings equipped with, often old-fashioned cooling units blowing cold air into the storage space (space cooling).

Potatoes are packed in 50 kg bags and placed on racks within the store. All produce is brought into and taken out of the store by manual labour. It appears the number of thermometers measuring product temperature levels is often very limited. Calibration of store thermometers is unusual and temperature fluctuations within the store are quite usual. Freezing temperatures may occur resulting in substantial losses of the (too) cold stored or even frozen products.

Substantial improvements in store design and management must be made as such will lead to lower energy costs, better product quality and reduction of losses:

- Construct more (than just one) storage bins within one store complex.
- Replace old-fashioned refrigeration equipment to save on energy.
- Run a maintenance schedule on the refrigeration equipment to save on energy.
- Clean of the storage rooms on a regular basis; at least once a year.
- Install a forced air distribution system.
- Install increased fan capacity to enhance air distribution for quicker, so more efficient, cooling to reduce energy costs.
- Install temperature measurement equipment and automatic temperature recording.
- Install software for optimal temperature control.

## 6.2 Post-harvest losses

Post-harvest losses are caused by pathogens (bacteria, fungi), sprouting and respiration. Losses are majorly physiological and pathological by nature.

Figure 16. **Estimated post-harvest losses (%).**

| Stages / level | States / U.T. | Percentage of Losses |
|---|---|---|
| 1. | 2. | 3. |
| Harvesting | Arunachal Pradesh, Himachal Pradesh, Meghalaya, Rajasthan | Upto 1 per cent |
| | Assam, Jammu & Kashmir, Karnataka, Manipur, Punjab, Tamil Nadu | Upto 2 per cent |
| | Bihar, Delhi, Haryana, Tripura, West Bengal | Upto 3 per cent |
| | Andhra Pradesh, Madhya Pradesh, Orissa, Sikkim, Uttar Pradesh | Upto 5 per cent |
| | Gujarat, Maharashtra | 5-6 per cent |
| Village Traders | Assam | 2-3 per cent |
| | Bihar | 5-10 per cent |
| | Himachal Pradesh | 1-2 per cent |
| | Karnataka | 2 per cent |
| | Kerala | 10 per cent |
| | Madhya Pradesh | 1-2 per cent |
| | Manipur | 1-2 per cent |
| | Meghalaya | 0.5 per cent |
| | Orissa | 1-2 per cent |
| | Sikkim | 2-4 per cent |
| | West Bengal | 3-6 per cent |
| Traders | Andhra Pradesh | 1-2 per cent |
| | Assam | 2 per cent |
| | Bihar | 5-10 per cent |
| | Gujarat | 5 per cent |
| | Himachal Pradesh | 1-3 per cent |
| | Jammu & Kashmir | 5 per cent |
| | Madhya Pradesh | 10-15 per cent |
| | Manipur | 3-5 per cent |
| | Meghalaya | 0.5 per cent |
| | Orissa | 2-5 per cent |
| | Punjab | 6 per cent |
| | Sikkim | 1 per cent |
| | Tripura | 10-15 per cent |
| | Uttar Pradesh | 10 per cent |
| | West Bengal | 4-6 per cent |

**Source :** Marketing of Potato in India, DMI, Ministry of Agriculture. Year – 1984, 2001.

Bihar, a large potato state, reports losses of more than 20%. Punjab, another important potato region, reports average losses of about 8%. Apparently store management expertise is available and should be utilized through training courses.

Figure 17. **A modern (8,000 tons) potato store for box storage commissioned in 2010.**

In 2011 the Government of India is providing financial support up to 40% of the construction costs of new cold stores.

# 7 Marketing

## 7.1 Grading and sorting

Grading is an important factor in the marketing process of potato. Grading of tubers is done both by hand as well as by graders i.e. hand operated grader or power operated grader.
The quality factors like size of tubers, conformity to the variety, tolerance limits for undersized and oversized tubers, percentage of diseased and damaged tubers, and dust and extraneous matters, etc. are taken into consideration.

There are different Agmark grade standards of table potato like oval varieties, or long, round varieties, these will bear the mark indicating the variety it belongs to and will be checked for any diseases, defect, cutting, greenness etc. and various other quality assurances.
India follows CODEX specification for potato products grading and sorting.

Handling and packaging of potatoes are done generally on the farm. After harvesting, the tubers are kept in a heaped condition temporarily and covered with straw. After a few days, sorting is done for separating the diseased and cut tubers. The sound tubers are packed in hessian cloth bags or net bags.

## 7.2 Transportation

Manual labour is very important in potato transportation.

a) Head Loads : The age old method of carrying produce by a person on the head. It is convenient and practiced for :
i) Places like in hilly areas.
ii) Carrying small quantity of produce.
iii) For transporting nearest market having short distance.

b) Bullock / Camel carts : Bullock / Camel carts are the primary means of transport in most rural areas. It is convenient and practiced for following **:**
i) Cheap and easily available conveyance for the farmers to transport 5-10 quintals of produce to short distant places.
ii) Operational cost is low.
iii) Easily manufactured by rural artisans from locally available materials (wood).
iv) Can be operated in muddy, *kutccha* or sandy roads.
v) This transport system creates employment to rural artisans.

c) Tractor trolley:
The use of tractor attached to a trolley is commonly used for transporting potatoes in many parts in the country. It is convenient and practiced for**:**
i) Carrying large quantity of produce in short duration of time.
ii) Suitable in surplus producing areas than the trucks for carrying produce to the primary assembling markets in the absence of *pucca* roads.

d) Trucks :
Large or bulk quantity of potatoes are carried by the trucks to the distant places throughout the country. It is convenient and practiced for**:**
i) Easy availability.
ii) Time saving.
iii) Quick movement of stocks.

iv) Door to door delivery.
v) Lower transit losses due to least handing of loading and unloading.

e) Railway Transport :
During harvesting season, considerable quantities of potato are transported by railway wagons. This is convenient and practiced for:
i) Suitable for carrying larger quantity of potatoes over long distances.
ii) Comparatively cheaper and safer mode of transport available through a wide network of railways.

Assembling

Assembling is the first step in marketing of farm produce. The agencies engaged in the assembling of potato are as below :
a) Producers
b) Village Merchants
c) Itinerant Merchants
d) Wholesale Merchants
e) Commission Agent
f) Producers Co-operative Societies

The major assembling markets are located in Uttar Pradesh, Punjab, West Bengal in which the assembling of potato is done along with other commodities.

The arrivals of winter crop potato contribute to about 85% of total production commencing from harvesting season stretching from Dec-Jan to March-April.

Generally most of the potato arrived in the markets are consumed within the state. However, in some cases, it has been noticed that a significant quantity of potato despatched to other states also in the country.

Figure 18. **Interstate transportation of potatoes within India.**

**Percentage of Potato Despatched to Other States**

| Sl No. | Name of Market | Percentage of potato despatched to other states |
|---|---|---|
| 1. | Ratlam | 80.97 |
| 2. | Shimla | 75.00 |
| 3. | Farukhabad | 70.00 |
| 4. | Bangalore | 60.00 |
| 5. | Delhi | 50.00 |
| 6. | Mettupalayam | 50.00 |
| 7. | Kamrup | 43.66 |
| 8. | Amritsar | 40.00 |

**Source :** Field Survey Reports,
Directorate of Marketing and Inspection,

The interstate movement of potato mainly takes place by road, rail and to some extent by river. The movements of potato from surplus states to the deficit states take place throughout the year in huge quantities specially during the glut situation in the peak season.

**Potato trading centres in India:**

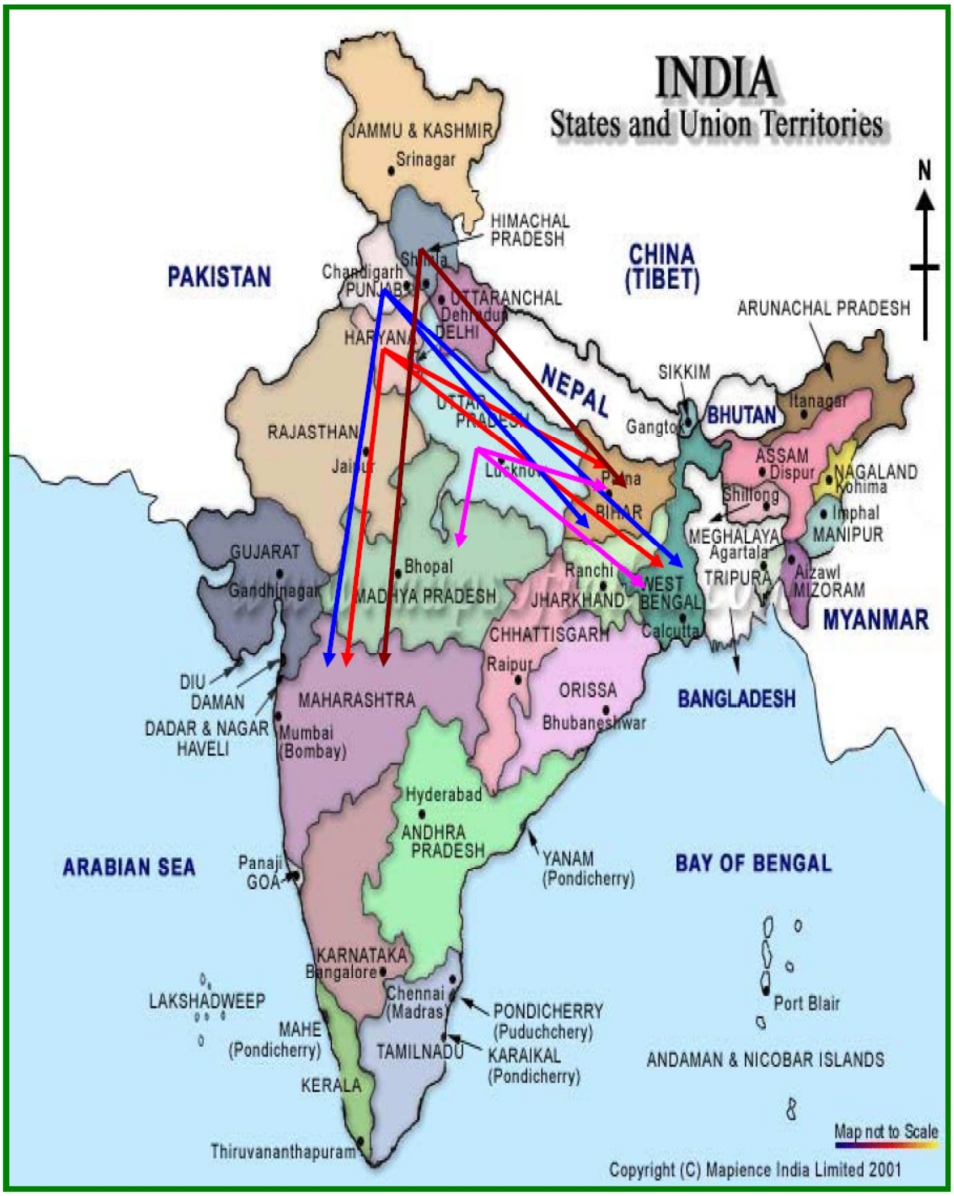
*Agra (Uttar Pradesh)*
*Hathras (Uttar Pradesh)*
*Kanpur (Uttar Pradesh)*
*Meerut (Uttar Pradesh)*
*Farukhabad (Uttar Pradesh)*
*Jalandhar (Punjab)*
*Ludhiana (Punjab)* Agra (Uttar Pradesh)
*Phul (Punjab)*
*Patiala (Punjab)*
*Ujjain (Madhya Pradesh)*
*Indore (Madhya Pradesh)*
*Dewas (Madhya Pradesh)*
*Hoogly (West Bengal)*
*Burdwan (West Bengal)*
*Howrah (West Bengal)*

Figure 19. **Trend of interstate potato transportation.**

**Trend of Interstate- Movement of Potato in India**

| Sl No | Despatched from | Despatched to |
|---|---|---|
| 1. | Punjab | Maharashtra, Bihar, West Bengal |
| 2. | Haryana | Maharashtra, Bihar, West Bengal |
| 3. | U.P. | Bihar, West Bengal, M.P. |
| 4. | H.P | Bihar, Maharashtra |

Figure 20. **Geographical display of interstate transportation of potatoes within India.**




# 7.3 Market structure

## 7.3.1 Marketing Channels

I) Private:

The different private agencies are operating in the market; such as Producers, Commission agents, Wholesalers, Retailers and consumers; and are involved in the route of marketing channels of potato. These are :

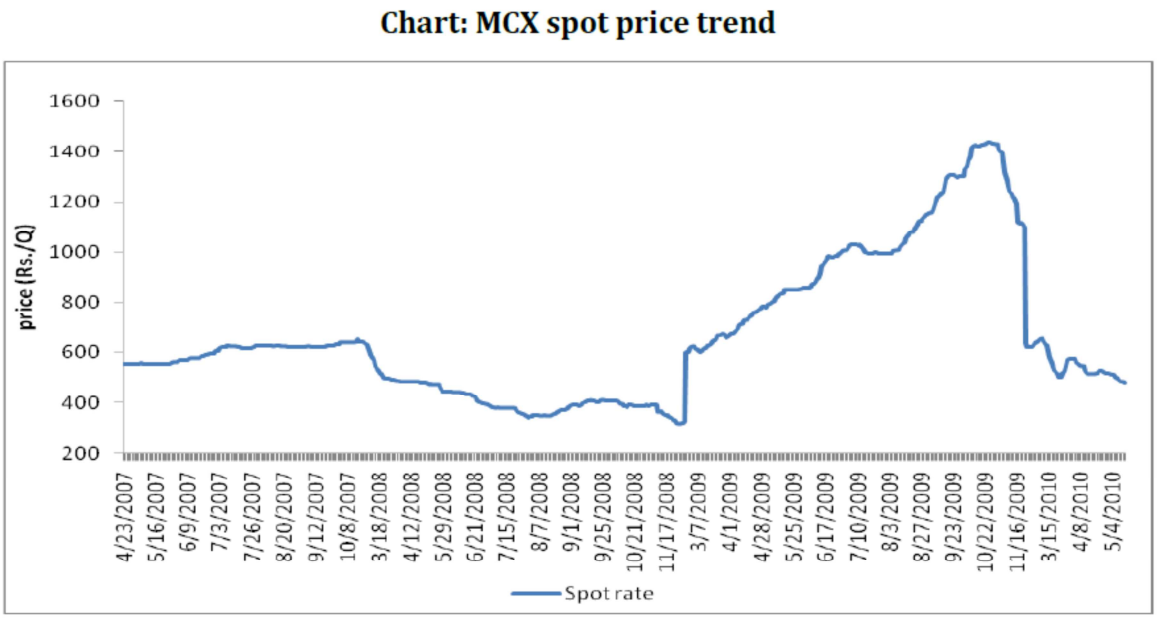
1) Producer ➡Cold storage ➡Commission agent ➡Wholesaler ➡Retailer ➡Consumer
2) Producer ➡Commission agent ➡Wholesaler ➡Retailer ➡Consumer
3) Producer ➡Wholesaler ➡Retailer ➡Consumer

On national level, the average potato price in May 2009 was Rs. 828.46 per hundred kg (Euro 0.13 per kg), and this went up to Rs. 1,405.29 (Euro 0.21 per kg) in October 2009. A rise of about 60% during the

storage season (= hot summer season in the plains of India).

Potato prices maintained its northward journey during 2009 due to lower production. This year (2011) prices are expected to remain in the range of Rs. 400-600 per hundred kg (Euro 0.06 – 0.09 per kg). As of now (April 2011), the spot rate is hovering around Rs. 500 per hundred kg at Agra market (Euro 0.075 per kg). The demand is likely to remain strong while supply will pressurize the rise in prices.

Figure 21. **Spot price trend of potatoes (April 2007-April 2010).**

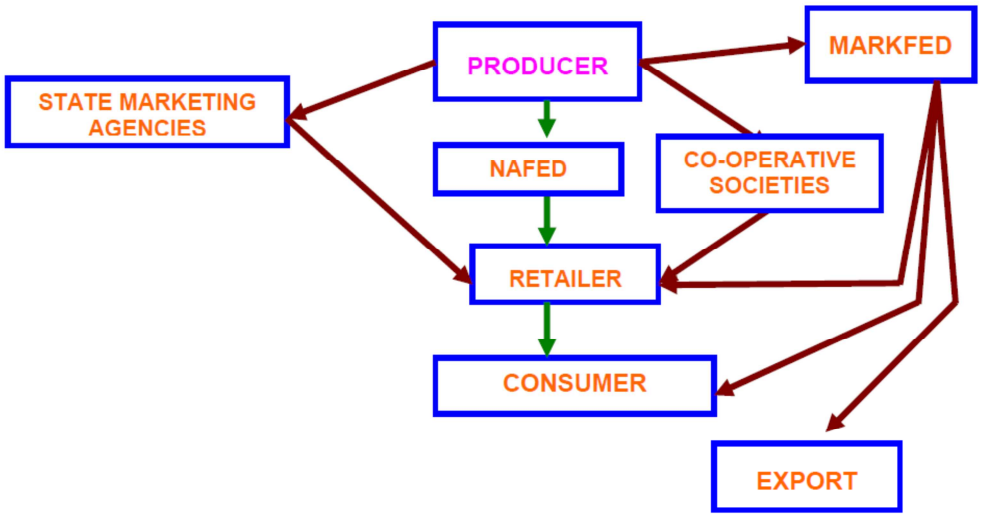



The potato prices have maintained their northward journey since it touched an average low of Rs. 320 per quintal in November 2008. The prices were down in late 2008 due to sluggish demand in the spot market and better production of potato in 2007-08. Prices witnessed a bull run since November 2009 due to limited supply and higher demand in the market.

The period from November to February is considered to be a lean period for potatoes as the next produce comes to the market by the month of March; hence, the demand remains strong while the supply goes down in this period.
In Northern, north-eastern region (the hilly regions) harvesting starts in the month of November and fresh Rabi produce comes in the market which drives the market down in the months of December and January. However, in southern, prices in the month of Aug-Sep is governed by arrivals from Hasan market (District in Karnataka) which starts from 15th Aug. The produce from Hasan will cater the market till the end of September after which, in the month of Oct – Nov there is again dearth of supply and prices goes up till November.

II) Institutional :
Due to price fluctuations and glut situation in the market, some institutions like National Agricultural Co-operative marketing Federation (NAFED), different state government agencies, co-operative societies are intervening in the domestic market and Agricultural and Processed Food Export Development Authority (APEDA) for export purpose to stabilize the prices. The institutions involved in the marketing channels of potato are as in figure 19.

Figure 22. **Institutions involved in the potato marketing channels.**




Retailers:

a. Most produce is sold at vegetable markets (mandi) in India.
b. Street vendors buy the produce from mandi.
c. Big processing companies presently buy from farmers however before they were forced to buy the produce from mandis in order to protect farmers and market chain.
d. The supermarkets are a new concept in India and started some 5 years ago (about 2005). Only a small percentage of produce is sold there, however this percentage will experience a boost in the coming years.

Marketing costs: Marketing costs are the actual expenses required for bringing potato from farm gate to the consumers. It includes the following costs:

- Handling charges at local points.
- Assembling charges.
- Transportation and storage costs.
- Handling charges by wholesalers and retailer to consumers.
- Expenses on secondary services like financing, risk taking and market intelligence.
- Profit margins taken out by different agencies.

Seasonal production pattern, limited alternative market outlets e.g. processing, and inadequate cold storage capacity result in heavy price reduction during the main harvesting months of January to March. Increased exposure to marketing and market realities are making more farmers aware that if potato could be stored by some cheap method for as little as two to three months, their profits would be higher. Given this, the indigenous potato storage methods are becoming popular with farmers.

## 7.4 Factors affecting price of Potato

The potato price is affected by a number of factors:

a. Area under cultivation in the major growing areas.
b. Weather in key growing regions particularly cold waves and heavy rains during tuber formation have a yield reducing effect.
c. Price of other vegetables.
d. Demand of potato from the major cities and food processing industries.
e. Potato price tends to go up during the planting period and eases down during the harvesting period.

f. Transportation charges from one place to another.
g. Potato growers and traders hoard the commodity before selling in expectation of better prices.
h. Potato can be kept in cold storages without spoilage for 5-6 months.

Figure 23. **A street market in New Delhi with onions and potatoes for sale.**

## 7.5 Direct marketing

The direct marketing system enables the farmers to meet the specific demand of wholesalers, traders, consumers according to their preferences from the farmers inventory of graded and certified produce on one hand and on the other hand helps the farmers to take advantage of favourable prices. This system has encouraged the farmers to undertake sorting, grading and quality marking at their farms. This model has been introduced in the name of APNI MANDI in Punjab and in the name of RYTHU BAZARS in Andhra Pradesh for fruits and vegetables.

## 7.6 Contract marketing

This was started for potato to satisfy the quality demand of the major food processors and for timely produce. For example: implementation of successful contract farming took McDonalds seven years and by 2007 McCain was confident enough to invest $40 million and set up a plant in Mehsana, Gujarat.
The farmers were introduced to the new technologies like drip irrigation, fertigation and other essential inputs necessary for the potato production suitable for French fries production.

In this agreement, the company contributes input, supplies and renders technical guidance. The company also bears the entire cost of transaction and marketing. The inputs and extension services provided by the agency include improved seed, credit, fertilizers, pesticides, farm machinery, technical guidance, extension, marketing of produce etc. Through contract marketing producers, especially small farmers, are participating in the production of good quality potato to get higher returns.

Contract Farming has enabled producers to adopt new technologies to ensure maximum value addition and access to new global markets. It also ensures efficient post-harvest handling and meeting specific needs of customers.

Pepsi (Frito-lay) has successfully contracted with the farmers of Maharashtra and Karnataka.

Many companies have entered into contracts with farmers for production and marketing of agricultural produce including potato. As for example, the Himalaya International Ltd. (HIL) has made backward linkage through contract farming in potatoes with farmers of Ponta Sahib in Himachal Pradesh. In this system, the

company provided seeds, organic manure and total technology to 150 farmers during 2005. The company has introduced baby potato skin stuffed with cheese and tomatoes for rapidly growing market involving constant innovation and diversity of cuisine. Being potato content low starch and high fibre content, these potatoes are better for health than large potatoes. The HCL is exporting IQF frozen potatoes to U.S.A and U.K.

In West Bengal, a similar system to contract marketing started. The Department of Food Processing Industries & Horticulture, Government of West Bengal has made an experiment through an arrangement between Frito-lay India Ltd and a few co-operative societies for supply of chip quality potato to the processing units since 2003-04. The varieties tried were Chipsona-1 and 2, Jyoti, Atlantic (US Variety) and Chandramukhi. On the basis of trial "Jyoti" was selected. Frito-lay India Ltd supplied G-2 micro tubers to some Co-operative Societies in Hoogly and Burdwan Districts at a fixed price. Co-operatives in turn supplied seeds to its growers. Initial results have been reported and are encouraging. Frito-lay buys a sizeable quantity of the chip trade potato so produced at a fixed price and also pay service charge to the societies on final procurement.

The participants are:
A. Frito-lay
a) supplying seed potatoes to each society under contract at a fixed price;
b) providing technical guidance and supervision;
c) testing the potato;
d) buying back the potato at a fixed price;
e) providing service charges to the society.

B. The Societies
a) making contract agreement with Frito-lay for growing chip grade potato through the member farmers;
b) procure and supply seed to the member farmers;
c) arrange cultivation and supply of potatoes of acceptable grade by the farmers;
d) arrangement of organizing training to the farmers by Frito- lay and experts from universities and other outsourcing.

C. The Government Department
a) maintain liaison with societies and Frito-lay;
b) providing training to farmers for getting desired grade potatoes.

## 7.7 Co-operative Marketing

The Co-operative marketing is the system by which a group of farmers join together to carry on some or all the processes involved in bringing goods from producer to consumer. In other words, it is the association of cultivators / farmers for the purpose of helping them to market their produce in a more profitable way than private trade system.

The members of a potato co-operative society sell their surplus produce to the society. Member farmers sell their produce to the society and they get an advance. After collecting the potato from the member, the society either processes it or sells it in the mandies or to the processors. Sometimes, considering the unfavourable prices prevailing in the market, the society stores the produce and sells later at a favourable price. As soon as the produce is sold, the society makes payment to the farmers.

The Potato Growers Co-operative Association in Gujarat, Farukhabad Co-operative Marketing Society in Uttar Pradesh etc. are associated with Co-operative marketing of potato. Besides, there are other co-operative organizations like NAFED which is a well-known organization because and its function as the National Apex Body of the cooperative marketing system in co-ordination with State level Marketing Federations, Regional and District level co- operative societies. The aim of NAFED is to promote co-

operative marketing of agricultural produce including potato and to ensure the farmers to get ready market as well as remunerative price for their produce.

## 7.8 Forward and Future Markets

In terms of price discovery and risk management the forward and future markets have been identified as an important tool for price stabilization. Presently, forward and future market system is followed in certain agricultural commodities including potato.

► The forward market supports two economic functions namely price discovery and price risk management which enables the traders and stockiest to protect against the risk of adverse fluctuation of prices. It is governed under the Forward Contract Regulation Act 1952.

► The future market facilitates the trading of potato for the purchase or sale of the commodity for future delivery where contracts are made on a future exchange on the basis of standard quality, quantity, delivery time, locations and the price. This makes the supply chain efficient and provide better price to the farmers.

## 7.9 Potato and price levels 2010 and 2011

Table potato in whole sale and retail markets in 2010 was on average IRS 3 at farm gate, 6 at whole sale and 10 at retail markets. Prices were lower in 2011 due to glut production from the 2010-2011 winter crops.

Most table potatoes for sale in Azadpur in early October 2011; one of the largest vegetable market in Asia (and India); had been cold stored since March 2011 and were healthy and without sprouts. The daily turnover at Azadpur is about 3,000 tons.

# 8 Processing

In India, processed potatoes currently constitute less than 0.5% of 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, starch etc.

The sector developing most rapidly is the snack foods sector, including potato chips.

Figure 24. **Potato and its usages in India.**

| Usage | Percentage of total production (%) |
|---|---|
| Table purpose | 61.47 |
| Seed | 21 |
| Processed | 0.5 |
| Export | 0.03 |
| Loss in Post harvest, handling, marketing and storage | 17 |

Source: NHRDF

Data on the processing volume are difficult to obtain, but it is known that potato is processed for snack industry. The installed potato processing capacity has almost tripled during 2006-2011; actual use has doubled (Table 9; information obtained in June 2011). The installed capacity represents 0.9% respectively of the total potato production in India.

Table 9 shows some global data on potato processing volume and share of total potato production. Emerging economies like China and India may have a tremendous potential in developing the processing markets when compared to the share of processed volume in emerged economies like EU and USA.

Table 9. **Installed potato processing capacity (tons) in India.**

| Company | Installed processing capacity | | |
|---|---|---|---|
| | 2006 | 2011 | Actual in operation in 2011 |
| PepsiCo | 80,000 | 150,000 | 130,000 |
| ITC | 0 | 50,000 | 33,000 |
| Balaji | 20,000 | 50,000 | 38,000 |
| Haldiram | 10,000 | 22,000 | 22,000 |
| Parle | 0 | 50,000 | 15,000 |
| Total | 110,000 | 322,000 | 238,000 |

The overall size of the snack food market is estimated at Rs. 45 to Rs. 50 billion (about Euro 680 – 750 million) per year. The market is reported to be growing at an annual rate of 7 to 8%. Potato chips is estimated to constitute nearly 85% of India's total salty snack food market of about Rs. 25 billion (about Euro 380 million).

Figure 25. **Quality assessment facility for potato chips in Azadpur (New Delhi); one of the largest vegetable markets in India.**

Table 10. **Some potato processing statistics (data 2006)**

| Processing statistics 2006 | |
|---|---|
| World potato production | 313.8 million MT |
| Processing volume | 30 million MT (excl. starch, China, India) or 9.5% |
| North America | 51% (USA 42%) |
| EU-27 | 45% |
| EU-5 | 38% (NL, GER 10%) |
| French fries/pre-fried | 62% |
| Processing volume | 43 million MT (incl. starch, China, India) or 14% |
| China and India | 1.3 million MT or 6% |

In the Rs. 19 billion (about Euro 290 million) branded (organized) snacks market, constituting over 40% of the market by value, Frito-Lay is estimated to command a market share of 45%, followed by Haldiram at 27% and ITC at 16%. The branded snacks market accounted for 16% by value and 12% by volume sales in 2007. According to a projection by Euromonitor International, the branded snacks market would reach a value of Rs 35 billion (about Euro 530 million) by 2012.

Figure 26. **A modern potato chips packaging unit at Balaji (Gujurat).**

## 8.1 Major players

Market leader in India is Frito-lay with a 45% market share. Haldiram's has a 27% market share. The market is far from stable: recently ITC, an IT/cigarette company are making huge inroads in the CPG market. ITC has managed to get a market share of 11% with its potato chip "Bingo" in just 6 month. Also a dairy manufacturer (Amul) just announced to move into the snack market. Key weapon in this war for the Indian snack market are the Indian flavours.

The development of the snack market has also created a growing demand for dehydrated potato products, used as raw material for snacks.

With regards to frozen potato products, India has long been handicapped by the lack of infrastructure for the frozen food distribution chain. Nevertheless, world's largest French Fry manufacturer McCain Foods is active in India since 1995. With the recent completion of the new McCain factory in Gujarat, the production of French fries in India has been brought to a new level.

## 8.2 Efforts made over 10 years – “Turning the Tables”

The McCain story in Gujurat.

- Contract farming initiated in Gujarat
- Starting from high quality seeds
- Switching to Drip Irrigation system – 100%
- Investments in low cost equipment- planter, digger, sprayer
- Handholding the farmer in agronomy practices
- Technical know-how to upgrade the traditional cold storages

Government restriction upon seed imports was one of the big hurdles that McCain agronomist had to face and they had to use Indian seed variety.

Initially frozen French fries was imported by McDonalds but now Gujarat farmers are producing the raw material by themselvestaking guidance from the McCain agronomist.

Recently Mandeep Singh, a Punjab farmer turned into French fry manufacturer, planned to start the production of frozen fries with his company Satnam Agro Products in Jalandar.

Intriguing aspect of the potato supply chain in India is the strong vertical integration: ITC bought earlier this year the Australian company Technico, that developed technology for rapid multiplication and variety improvement. Also the company Merino Industries (dehydrated potato products among many other products) has its own tissue culture laboratories for multiplication and potato variety development.

Hence, certainly the potato processors have concerns about potato quality and doing their best in finding the best solution under conditions.

## 8.3 Export/import

India exports a very marginal part of its potato output constituting about 0.5% to 1% for the world’s total potato exports. As per the Directorate of Economics and Statistics, India exports potato, to the tune of around 184,961 tonnes valued at Rs. 11,503.59 lakh (about Euro 17 million) to countries like Sri Lanka, Nepal, Mauritius, Singapore, UAE and Japan.

Russia encountered severe potato shortages in 2011. India was not able to export part of its 2010-2011

glut production as the Russian markets demanded Sante potatoes. Sante is a Dutch potato variety.

Export to EU encounters the problem of the Q(uarantine) status of potatoes grown in India. EU blocks all potato imports from India.

## 8.4 Trends

In India, the Central Potato Research Institute has played a key role in providing technological innovations in terms of cultivars, production technologies, plant health management, value addition and processing. An institutional arrangement at regional level could be made for the import of suitable promising varieties from donor countries having similar agro-climatic conditions.

The annual growth rate of potato is higher than other major food crops in respect of area, production and productivity. In the year 2002-2003, the production was 25 million tonnes while it was 5 million tonnes during 1970. Hence, owing to its significant growth in production, bumper yields have been observed almost in every year. Due to the bumper crop, and lack of post-harvest management, glut situations in the market for the surplus yield rise every year which ultimately result in drastically decline of the prices.

The volume of potatoes processed into various products is low in India, about 1 % processed into chips, and much higher in NW European and North American countries. 40-50 % of the national potato production in USA is processed into French fries, chips and other products. Belgium and Germany are developing along a similar pattern. The volume of potatoes processed in The Netherlands is very high, about 75 %, and consists of about 40 % into food products and about 30 % processed into potato starch.

Prospects for increased processing in India are bright due to the large share of middle and high income groups in the Indian society. Such groups are interested in new products have purchasing power to buy and consume processed products.

# 9 Bottlenecks and recommendations

## 9.1 Bottlenecks

Improvement of India's potato sector is confronted by various factors.

a. Inadequate supply of healthy planting material at reasonable prices due to high transportation cost of seeds from north India, distance of more than 2,000 km.
b. Old degenerated seed planted for many generations by small farmers.
c. Adoption of suboptimal management practices due to farmers' and extension workers' unawareness of improved agro techniques for informal quality seed production.
d. Fast degeneration of tuber seeds by viruses due to farmers ignorance of integrated disease management practices.
e. Unorganized informal seed producer, such as North and Northwest India.
f. Lack of knowledge of appropriate seed storage practices.
g. Shifting (jhumi) cultivation in some areas in which land quality has been degraded by soil erosion and nutrients loss.
h. Indiscriminate use of chemical pesticides has resulted in the emergence of more aggressive pests because of resistance development, residual problems in food and drinking water, and ecological imbalance as a result of the elimination of beneficial micro-organisms and insects. Therefore, for sustainability of the potato crop, these biotic stresses need to be managed through eco-friendly measures supported by need-based and judicious use of chemicals to achieve high economic returns without disturbing the environmental balance.
i. The use of large quantities of pesticides by the farmers, especially for the control of late blight in the potato, has created problems of groundwater pollution, toxic residues in table potato, resistance development in pests and ecological imbalance. Only need-based fungicidal spray based on disease forecasting and cultivar resistance should be advocated. Research priorities.
j. Adoption of advanced techniques like micro-propagation, micro-tuberization and hydroponics for production of pre-basic seed.
k. Adoption of advanced techniques like ELISA, NASH, Qrt-PCR etc. for virus diagnosis and seed certification.
l. TPS development by apomixis and parthenogenesis in commercial potato cultivars.
m. Determination of an optimum harvesting period for processing cultivars.
n. The development of energy-efficient storage conditions that do not compromise processing attributes.
o. The development of new processes that have minimal effect on the environment, and products that have lower fat content and fewer additives but maintaining crispiness.
p. Reduction or elimination of enzymatic oxidation of cut surfaces.
q. Lack of adoption of potato processing technology that will not only increase the returns but will also boost the quality of produce.

Concerns over climate change, that is rise in temperature, which has resulted in worldwide decrease in production (J.P. Singh raises his concern in paper climate change and potato production in India.)

## 9.2 Recommendations for R&D

India is an important potato country considering its large production acreage, its high production volume and its long established R&D program. The potato is the third most important food crop after rice and wheat, present per capita availability is calculated at 30 kg. Per capita availability of rice, wheat and maize was 116, 70 and 15 kg respectively in 2009 (Source of data: FAO).

Our study has identified a number of approaches for developing a potato research program between India

and The Netherlands.

### 9.2.1 Good Agricultural Practices (GAP)

The concept of Good Agricultural Practices (GAP) is rather new to India. GAP is best described by production according to the wishes of consumers, retailers and processors. This package of wishes mostly is best summarized by using lower amounts of mineral fertilizers and lower inputs of crop protection chemicals in production and storage.

### 9.2.2 Decision Support Systems

Part of the GAP concept is the introduction of Decision Support Systems (DSS). DS systems are available for late blight control and lead to lower application rate of chemicals required for late blight control. A DSS for late blight is expected to be most effective in the spring crops in the plains.

### 9.2.3 Yield gap analysis

Computer calculated potato yield levels show substantial differences between calculated yields and famers' yields. This finding implies room for yield increase through a concentrated effort. The factors responsible for the yield gap need to be identified and prioritized. Emphasis needs to be put into removing the high prioritized yield constraints.
Eventually higher yield levels are expected to reduce the cost of production per kilogram and making the potato even more attractive as a food crop.

### 9.2.4 Potato Cyst Nematodes

Potato Cyst Nematodes (PCN) is often a major pest in potato production regions and has been found in three regions in India. The best way to control PCN is through resistance management. Resistance management includes a number of inputs: resistant varieties, laboratory facilities, soil sampling techniques and trained personnel.

### 9.2.5 Storage and handling

About 30-40% of the potato crop in India is lost due to poor handling and storage. This applies particularly to the spring crops which are harvested at the onset of the hot summer period. The economics of storage show the benefits of storing the crop under cool conditions. The application of sprout inhibition compound(s) will enhance the effect of cold storage in reducing post-harvest losses and stabilizing quality. Introduction of sprout inhibition compounds like CIPC and ethylene must be considered.

### 9.2.6 Indian Potato Platform

Private and public potato parties should meet on a regular basis. Therefore the establishment of an Indian Potato Platform is recommended as such body will help in formulating a national strategy for enhancement of the potato industry. Producers, traders, retailers, processors and government are the candidates for such a platform. The platform will follow up on market developments and support the development of the potato sector in India.

### 9.2.7 Meeting the specs

Meeting specifications for processing (size, dry matter concentration reducing sugars, defects) is a pre-requisite for a client oriented potato sector. Clients whether consumers, retailers or processors have their wishes, requirements. They want their product produced according to such requirements: meeting the specifications.

# 10 Opportunities

The project team presented its findings in a workshop on Wednesday 5 October 2011 in New Delhi. The workshop was attended by about 60 participants from the potato industry in India. The program is in appendix 2.

## 10.1 Approach to potato chain development in India as discussed during the seminar

Approach to potato chain development in India
- Produce potatoes according to the wishes of market parties
- Prioritize yield limiting factors
- Increase yield levels
- Reduce production costs per kg
- Introduction of Good Agricultural Practices (GAP)
- Introduction of DuRPh genes in Indian potato breeding

## 10.2 Opportunities and partners

The participants discussed the opportunities which are listed below and specified for the partners in the particular field of cooperation.

Development of varieties and the seed potato industry
- Partners:
    - Central Potato Research Institute (CPRI)
    - Indian seed potato producers
    - Plantum, the Dutch association of seed traders
    - NAK, the Netherlands Inspection Service
    - Dutch seed potato companies

Introduction of Good Agricultural Practices (GAP)
- Partners:
    - Indian potato growers
    - Indian (large) retailers
    - Potato processors in India
    - Central Potato Research Institute (CPRI)
    - Dutch Decision Support Systems companies
    - Wageningen University & Research centre

Improving storage, storage management and processing qualities
- Partners:
    - Indian storage owners, potato growers, retailers and processors
    - Dutch store construction companies
    - Central Potato Research Institute (CPRI)
    - Wageningen University & Research centre

Yield gap analysis and yield increase goals

- Partners:
    - Indian potato growers
    - Indian Agricultural extension service
    - Central Potato Research Institute (CPRI)
    - Wageningen University & Research centre

Production of high quality raw material for potato processing factories

- Partners:
    - Indian potato growers, store owners, potato processors
    - Dutch store construction companies, potato processors
    - Central Potato Research Institute (CPRI)
    - Wageningen University & Research centre

# Appendix 1. Prices potato and potato products New Delhi – 3 October 2011

French fries

KFC

| package | weight | IRS | price IRS per kg | price Euro per kg |
|---|---|---|---|---|
| regular | 65-75 grms | 39 | 557 | 8.32 |
| medium | 95-110 | 55 | 550 | 8.21 |
| large | 125-135 | 65 | 500 | 7.46 |
| Supply: | McCain (deepfrozen from Gujurat) | | | |

McDonalds

| package | volume | IRS | Gram | price IRS per kg | price Euro per kg |
|---|---|---|---|---|---|
| small | 24-28 strings | 45 | | | |
| medium | 48-56 | 55 | | | |
| large | 96-112 | 65 | | | |
| Supply: | McCain (deepfrozen from Gujurat) | | | | |
| | Lamb Weston (deepfrozen from US) | | | | |

Deepfrozen French fries Big Bazar (DLF shopping mall)

| make | package | weight | IRS | price IRS per kg | price Euro per kg |
|---|---|---|---|---|---|
| McCain | plastic bag | 750 | 90 | 120 | 1.79 |
| McCain | plastic bag | 450 | 60 | 133 | 1.99 |
| Himalay Fresh | plastic bag | 450 | 59 | 131 | 1.96 |

Chips in Big Bazar( DLF shopping mall)

| make | weight | IRS | price IRS per kg | price Euro per kg | fat % |
|---|---|---|---|---|---|
| Uncle chips (= Lays) | 20 | 72 | 3,600 | 54 | 35 |
| Lays Onion | 55 | 180 | 3,273 | 49 | 34 |
| Lays Spanish | 55 | 180 | 3,273 | 49 | 33 |
| Bingo Ketchup | 20 | 66 | 3,300 | 49 | 33 |
| Bingo Extra | 20 | 79 | 3,950 | 59 | 33 |
| Bingo International | 20 | 66 | 3,300 | 49 | 35 |
| Tasty Tweet | 20 | 65 | 3,250 | 49 | 33 |
| Parle's | 10 | 36 | 3,600 | 54 | |

Fresh potato in Big Bazar (DLF shopping mall)

| make | product | weight | price | price IRS per kg | price Euro per kg |
|---|---|---|---|---|---|
| Orgavita | organic potato | 1,000 | 32 | 32 | 0.48 |
| Baby potato | very small sizes | 1,000 | 20 | 20 | 0.30 |
| Loose potato | medium sizes | 1,000 | 9 | 9 | 0.13 |
| Potato Pahari *) | new potato | 1,000 | 24 | 24 | 0.36 |
| Potato Oorja | sugar free | 1,000 | 12.90 | 12.90 | 0.19 |

*) from Pahari region in HP

# Appendix 2. Program Workshop 5 October 2011

**Workshop on**
**INDO-DUTCH**
**CO-OPERATION IN POTATO CHAIN**
**Focus on Production, Storage, Processing, Marketing & Export**

**Launch event of Potato Expo India 2012**

**October 5th 2011,**
**Clarion Hotel, New Delhi**
Shaheed Jeet Singh Marg, 110016 New Delhi
+91 1141200000
www.clarionhotels.com

| | |
|---|---|
| 09:30 hrs | Registration |

**Inaugural Session**

| | |
|---|---|
| 10.00 hrs | Welcome address by **Mr. S Jafar Naqvi**, Chief Coordinator, Potato Expo India |
| 10.10 hrs | Welcome address by **Mr. Henk van Duijn,** Counsellor for Agriculture, Nature and Food Quality of the Netherlands |
| 10.20 hrs | "Indo-Dutch cooperation opportunities in Potato Research" By **Dr. Bernard de Geus**, MD Top Institute Green Genetics the Netherlands |
| 10.30 hrs | Address by **Mr. Shailendra Kumar**, Director, National Horticulture Mission, MOA |
| 10.45 hrs | Keynote address by **Dr. Raveendra Kumar Sharma**, National Horticulture Board |
| 10.55 hrs | Vote of thanks |
| 11.00 hrs | Tea Break |

**Technical Session: 1**

11.20 hrs Opening remarks by the session Chairman,
by **Mr. Ernst van den Ende,** MD Plant Science Group, Wageningen University & Research

11.30 hrs "Relevance of Potato Industry in India, and opportunities for co-operation"
by **Dr. Govindakrishnan**, Principal Scientist, CPRI, Shimla

11.50 hrs "Potential potato yields in the Indian plains"
by **Dr. Anton Haverkort**, Wageningen University & Research Centre

12.10 hrs "Modern seed potato production, storage and processing in Northern India"
by **Mr. Jang Bahadur Singh Sanga M.S.***, Secretary-General POSCON

12.30 hrs "Innovative post-harvest technologies in potato production"
by **Mr. Jan Jappe Alberts**, Tolsma Techniek

12.50 hrs Q & A and summing up by the chairman

13.00 hrs Lunch Break
Hosted by Wageningen University & Research Centre and
the Netherlands Ministry of Economic Affairs, Agriculture and Innovation

**Technical Session: 2**

14:00 hrs Opening remarks by session Chairman,

14.10 hrs "Prospects of modern potato processing in India"
By **Mr. Narinder S Kochhar**, Director, Kiron Hydraulic Needs Pvt Ltd.

14.30 hrs "Consumer driven potato and food innovation,"
By **Dr. A.K. Tyagi**, Group President, Haldiram Group

14.50 hrs "Findings and prospects of co-operation in the potato chain"
By **Mr. Romke Wustman**, Wageningen University & Research Center

15.10 hrs Panel discussion: Innovation in the potato chain
Moderator: **Devangshu Dutta**, MD Thirdeyesight
Panel members:
- Jang Bahadur Singh Sanga, POSCON
- Bhavana Vishwanath, Tolsma
- Jan Jappe Alberts, Kiremko
- Rohit Bhandari, Omnivent
- Narender S Kochhar, Kiron Hydraulic Needs
- Anton Haverkort, WUR

16.15 hrs Closing remarks by Chairman

16.30 hrs Closure

# Appendix 3. Calculating attainable potato yields in India

**Calculating attainable potato yields in India**

**Methodology**

In order to know whether your crops perform well in their environment and realise as much of their potential as in other areas or countries, it is necessary to know what the potential is. Obviously a short winter crop in cloudy short days will yield less than a summer crop in mountainous areas. Three levels of yields can be distinguished: potential yield, attainable yield and actual yields. Calculating and collecting those yields allows for benchmarking within between regions and seasons.

The first important driver is the temperature that drives development such as sprout growth and emergence and initial leaf development. Figure 1 shows that the temperature trails behind solar radiation the second important driver as it determines the growth rate. The length of the growing season – hence the period over which the crop can intercept solar radiation - is determined by the frost free period. In some areas the growing season is determined by the heat free period (e.g. Bengal) or by the frost and heat free period.

An example of the foliar development during the growing season is depicted in figure 2. The objective of growers is to achieve 100% ground cover as early as possible in the growing season for as long as possible to allow the crop to intercept the maximum amount of solar radiation. Early planting of well sprouted seed then is important to achieve an early crop establishment and a good supply of water and nutrients (especially nitrogen) and a sufficient lateness of the variety to complete a growth cycle that matches the length of the available season.

The intercepted radiation is converted into biomass (photosynthesis) and as figure 3 shows: there is a linear relationship between intercepted radiation and yield. The slope of yield (g $m^{-2}$) and radiation (MJ $m^{-2}$) equals g $MJ^{-1}$. The tubers are formed somewhat later (later with late varieties and longer days) and their weight increase is also linearly correlated with intercepted radiation.

The resulting pattern of growth of the foliage and tubers is shown in Figure 4.

Figure 1. **Development of global solar radiation and temperature over the year in the northern hemisphere.**

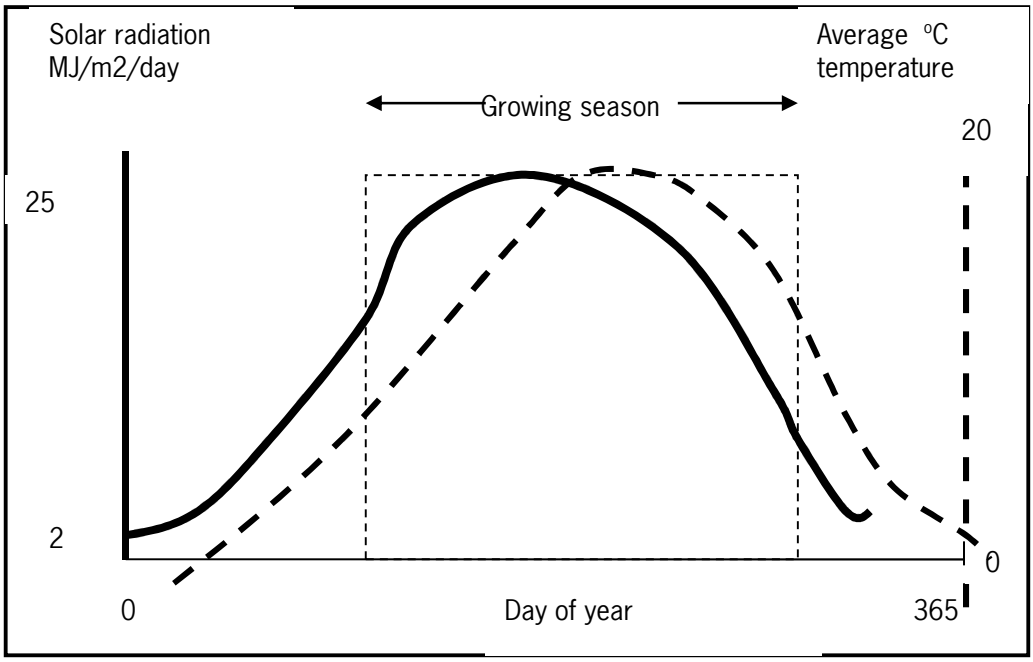



Figure 2. **Example of development of ground cover with green foliage between planting and haulm killing**.

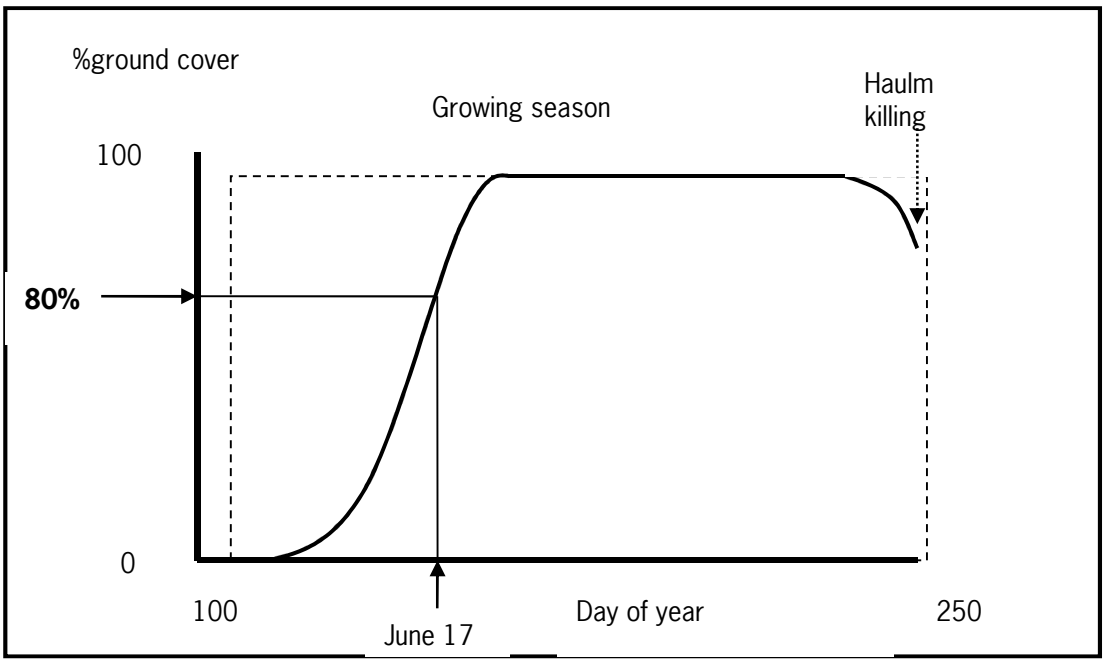


Figure 3. **Total and tuber dry mass increase versus the cumulative amount of intercepted solar radiation.**

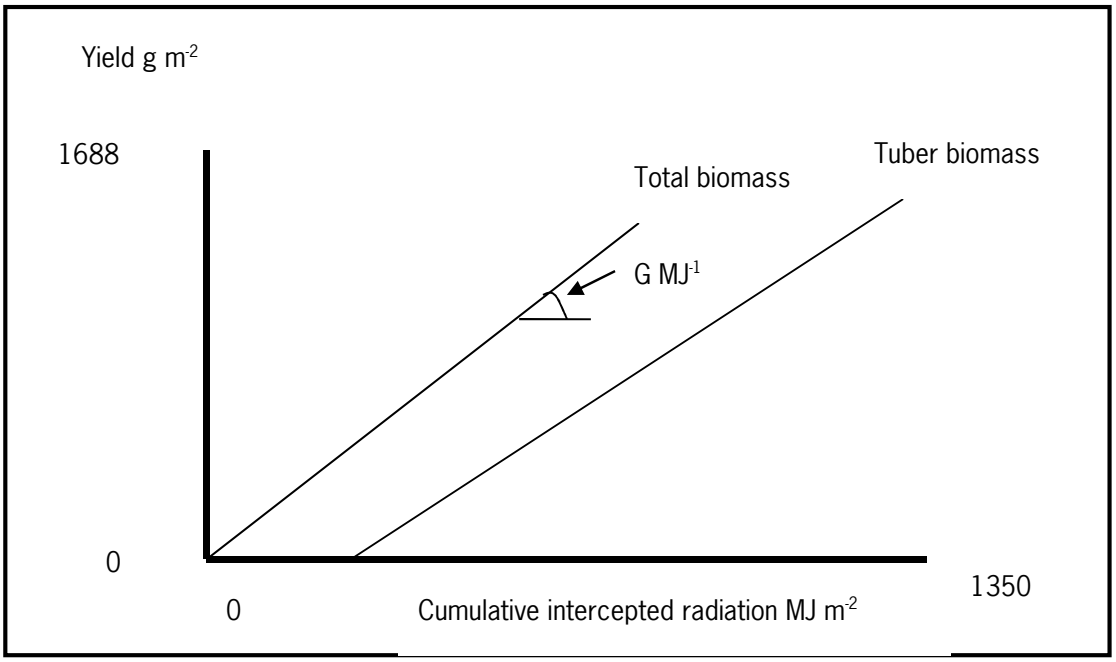
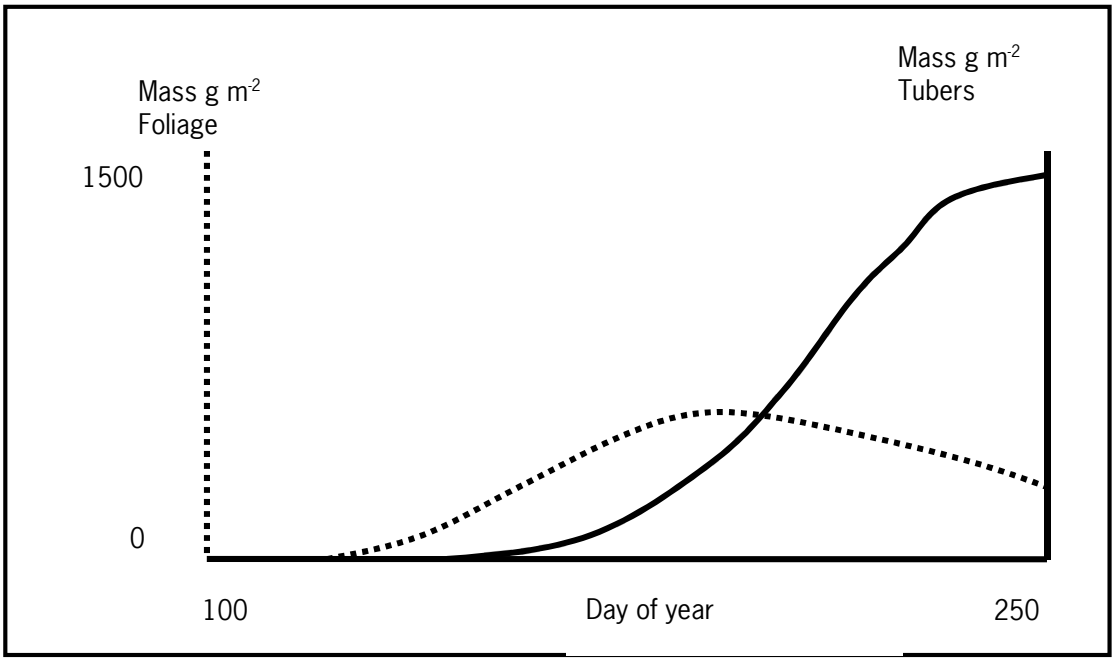



Figure 4. **Growth of foliage and tubers over the growing season.**



**Calculation of yields**

From the above it is clear that potato yields are calculated as follows

Y = R x E x Hi / DMC, with:

- Y = fresh potato yields (g $m^2$)
- R = solar global radiation (MJ $m^2$) (= 2 x photosynthetically active radiation (PAR)
- E = radiation use efficiency (= 2.5 g $MJ^{-1}$ PAR or 1.25 g $MJ^{-1}$ global radiation)
- Hi = harvest index (= 0.75 = proportion of all dry matter produced that end up in the tubers)
- DMC = dry matter concentration = 0.20 (20% dry matter, 80% water)

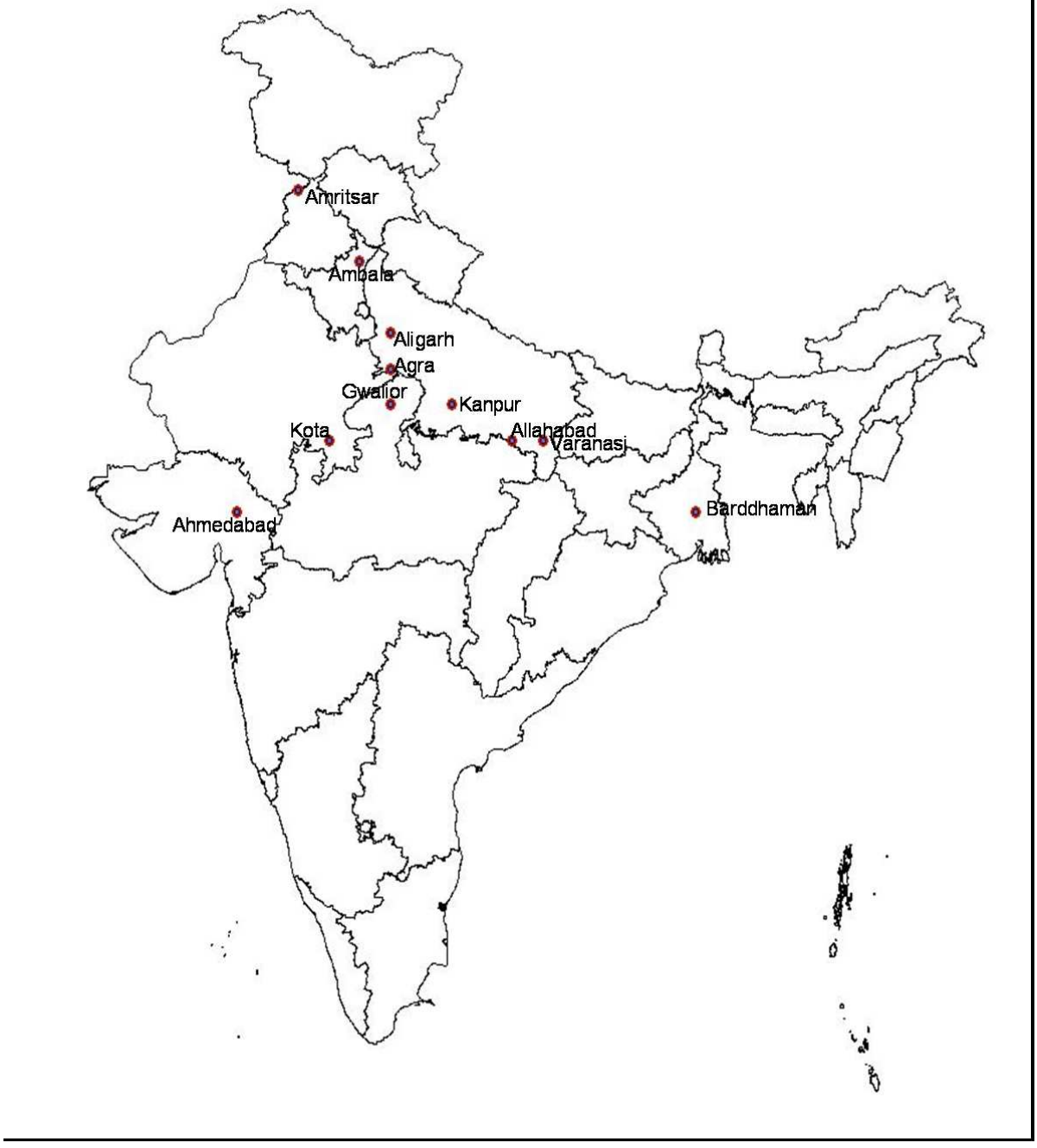
So to calculate attainable yields in general the model needs:

- Temperature (sum) in daydegrees (dd) as of planting to calculate emergence date (assumed is 0.7 mm/dd sprout growth rate with soil temperature = average day/night temperature.
- Ground cover calculated from the temperature sum as of emergence (assumed is that it takes 650 daydegrees for the crop to reach 100% ground cover
- Solar radiation data MJ/m2/day. Assumed is that Tmax below 8 degrees is E = 0, than increases with temperature, is optimal between 20 and 25 degrees and declines to 0 again at Tmax above 33 degrees.
- Planting and harvest dates to start and to stop the calculations.

Attainable yields are lower than the potential yields (that assumes theoretical maximum) but are those achieved when all possible care is given to the crop. This is not necessarily the economic optimum. Yields achieved on small plots in trials or occasionally by the best farmers can be considered close to attainable yields and often are about 2/3 of potential yields. Attainable yields can be approached by either a trialling best technical means or (cheaper) by a simple set of calculations. Attainable yields are based on a few essential actual crop data such as when were the crops planted and when did haulm killing take place.

**Weather data and model runs**

Long term weather data kindly supplied by mr Rajneesh Rajput Technical Officer at CPRI, Shimla were taken from sites shown on the map below.




The date are shown in the tables on page 5-8.
The tables on the following pages show the meteorological data and model runs of the 10 sites. PET data of Varanasi were missing so there those of Allahabad were used.

| Station | Month | Temp-Max | Temp-Min | Solar R MJ/m2 | Rainfall (mm/month) | PET (mm/month) |
|---|---|---|---|---|---|---|
| **Agra** | January | 22.2 | 8 | 14.32 | 12 | 54.7 |
| | February | 25.2 | 10.3 | 16.48 | 12 | 72.4 |
| | March | 32 | 15.8 | 17.96 | 8 | 111.5 |
| | April | 38.5 | 22.2 | 21.19 | 7 | 156.6 |
| | May | 41.5 | 26.3 | 24.57 | 15 | 181.1 |
| | June | 40.7 | 28.5 | 25.96 | 53 | 180.1 |
| | July | 35.2 | 26.7 | 24.84 | 194 | 140.7 |
| | August | 33.7 | 25.7 | 19.84 | 266 | 120 |
| | September | 34.4 | 24.3 | 17.15 | 121 | 120.6 |
| | October | 34.2 | 19.8 | 16.31 | 23 | 111.1 |
| | November | 29.7 | 13.6 | 13.55 | 6 | 68.8 |
| | December | 24 | 9.1 | 12.78 | 5 | 51.4 |
| | Site | Alt | Lat | Long | | |
| | Agra | 160 | 27.183 | 78.017 | | |
| | DOP | 17-Oct | LGP | 100 | | |

| Station | Month | Temp-Max | Temp-Min | Solar R MJ/M2 | Rainfall (mm/month) | PET (mm/month) |
|---|---|---|---|---|---|---|
| **Ahmadabad** | January | 28.2 | 11.8 | 16.45 | 2 | 108.3 |
| | February | 30.3 | 13.8 | 19.51 | 1 | 118 |
| | March | 35.5 | 18.8 | 22.77 | 1 | 174.4 |
| | April | 39.7 | 23.7 | 23.67 | 2 | 212.3 |
| | May | 41.5 | 26.2 | 24.98 | 15 | 261.2 |
| | June | 38.4 | 27.2 | 25.52 | 94 | 217.1 |
| | July | 33.4 | 25.6 | 20.50 | 261 | 154.4 |
| | August | 31.7 | 24.6 | 21.87 | 253 | 132.8 |
| | September | 34 | 24.2 | 15.12 | 109 | 142.8 |
| | October | 35.7 | 21.1 | 14.76 | 17 | 138.7 |
| | November | 32.7 | 16.6 | 16.19 | 11 | 108.4 |
| | December | 29.2 | 13.1 | 15.63 | 4 | 99.7 |
| | Site | Alt | Lat | Long | | |
| | Ahmadabad | 60 | 23.033 | 72.617 | DOP 31 oct | LGP 120 d |

| | **Agra** | **Ahmadabad** |
|---|---|---|
| Growing period (days) | 100 | 120 |
| Days between planting and emergence | 11 | 11 |
| Days emergence to 100% ground cover | 29 | 27 |
| Days between 100% ground cover and harvest | 60 | 82 |
| DM tuber yield (ton DM/ha) | 8,8 | 10,1 |
| **Fresh tuber yield (ton/ha)** | 44,1 | **50,7** |
| Soil field capacity (mm water / m soil) | 110 | 110 |
| Irrigation point (mm water / m soil) | 50 | 50 |
| Precipitation between planting and harvest | 44 | 19 |
| ETP between planting and harvest | 132 | 352 |
| Accumulated precipitation deficit (mm) | 95 | 338 |
| Soil water reserve (mm) | 30 | 30 |
| Irrigation need (mm) | 65 | 308 |
| **Irrigation need per ton fresh potato (mm)** | 1,48 | **6,08** |
| | | |

| Station | Month | Temp-Max | Temp-Min | Solar R MJ/M2 | Rainfall (mm/month) | PET (mm/month) |
|---|---|---|---|---|---|---|
| **Aligarh** | January | 21.7 | 7.5 | 13.76 | 16 | 59.7 |
| | February | 24.8 | 9.8 | 15.46 | 14 | 77.7 |
| | March | 30.7 | 14.8 | 21.48 | 8 | 127.5 |
| | April | 37 | 20.6 | 21.47 | 6 | 173.2 |
| | May | 41.2 | 26.2 | 22.59 | 14 | 220.2 |
| | June | 40 | 28.3 | 23.55 | 41 | 212.1 |
| | July | 34.9 | 26.7 | 20.65 | 225 | 152.1 |
| | August | 33 | 25.7 | 19.72 | 241 | 126.1 |
| | September | 33.5 | 24.5 | 17.54 | 171 | 131.2 |
| | October | 33.4 | 19 | 14.66 | 35 | 117.2 |
| | November | 29 | 12.1 | 12.71 | 2 | 83 |
| | December | 23.7 | 8.3 | 11.88 | 4 | 61.1 |
| | Site | Alt | Lat | Long | | |
| | Aligarh | 180 | 27.84 | 78.08 | | |
| | DOP | 1-Oct | LGP | 120 | | |

| Station | Month | Temp-Max | Temp-Min | Solar R MJ/M2 | Rainfall (mm/month) | PET (mm/month) |
|---|---|---|---|---|---|---|
| **Allahabad** | January | 23.8 | 8.3 | 15.65 | 21 | 70.6 |
| | February | 26.1 | 10.6 | 17.79 | 15 | 82 |
| | March | 33.2 | 16.1 | 19.82 | 11 | 135.2 |
| | April | 39.4 | 21.7 | 24.81 | 4 | 184.7 |
| | May | 41.7 | 26.7 | 24.23 | 4 | 262.4 |
| | June | 39.4 | 28.2 | 23.60 | 74 | 215.5 |
| | July | 33.2 | 26.7 | 16.15 | 278 | 145.9 |
| | August | 31.7 | 26.1 | 14.63 | 360 | 124.1 |
| | September | 32.7 | 25 | 14.50 | 170 | 128.8 |
| | October | 32.2 | 19.3 | 16.41 | 26 | 125.8 |
| | November | 28.2 | 12.1 | 14.54 | 7 | 86.5 |
| | December | 24.3 | 8.3 | 14.87 | 7 | 64.9 |
| | Site | Alt | Lat | Long | | |
| | Allahabad | 60 | 25.45 | 81.85 | | |
| | DOP | 13-Oct | LGP | 120 | | |

| | **Aligarh** | **Allahabad** |
|---|---|---|
| Growing period (days) | 120 | 120 |
| Days between planting and emergence | 10 | 11 |
| Days emergence to 100% ground cover | 26 | 30 |
| Days between 100% ground cover and harvest | 84 | 79 |
| DM tuber yield (ton DM/ha) | 10,2 | 13,4 |
| **Fresh tuber yield (ton/ha)** | **50,8** | **67,0** |
| Soil field capacity (mm water / m soil) | 110 | 110 |
| Irrigation point (mm water / m soil) | 50 | 50 |
| Precipitation between planting and harvest | 71 | 56 |
| ETP between planting and harvest | 235 | 235 |
| Accumulated precipitation deficit (mm) | 194 | 189 |
| Soil water reserve (mm) | 30 | 30 |
| Irrigation need (mm) | 164 | 159 |
| **Irrigation need per ton fresh potato (mm)** | **3,23** | **2,37** |

| Station | Month | Temp-Max | Temp-Min | Solar R MJ/M2 | Rainfall (mm/month) | PET (mm/month) |
|---|---|---|---|---|---|---|
| **Amritsar** | January | 19.3 | 3.7 | 10.94 | 24 | 38.2 |
| | February | 21.6 | 6 | 12.74 | 31 | 52.3 |
| | March | 26.5 | 10.8 | 16.99 | 42 | 90.1 |
| | April | 33.7 | 16.2 | 21.05 | 24 | 129.8 |
| | May | 38.7 | 21.1 | 25.24 | 18 | 167.6 |
| | June | 39.4 | 24.6 | 25.44 | 57 | 182.5 |
| | July | 35 | 25.2 | 20.64 | 214 | 146.1 |
| | August | 34.2 | 25.1 | 22.46 | 182 | 133.6 |
| | September | 34.5 | 22.2 | 19.70 | 100 | 120 |
| | October | 32.2 | 15.1 | 16.88 | 15 | 97.7 |
| | November | 27.1 | 8.6 | 13.57 | 6 | 59.8 |
| | December | 21.2 | 4.4 | 11.95 | 18 | 39.2 |
| | Site | Alt | Lat | Long | | |
| | Amritsar | 200 | 31.633 | 74.866 | | |
| | DOP | 6-Feb | LGR | 90 | | |

DATA OR PLANTING DATE MAY NOT BE CORRECT AS THEY LEAD TO TOO LOW YIELD

| Station | Month | Temp-Max | Temp-Min | Solar R MJ/M2 | Rainfall (mm/month) | PET (mm/month) |
|---|---|---|---|---|---|---|
| **Barddhaman** | January | 26.2 | 12.6 | 15.99 | 13 | 73 |
| | February | 28.6 | 14.8 | 16.96 | 13 | 85.7 |
| | March | 34 | 20.1 | 17.55 | 19 | 140.9 |
| | April | 37.5 | 24.2 | 21.95 | 44 | 170.3 |
| | May | 32.2 | 25.7 | 21.75 | 84 | 167.7 |
| | June | 34.7 | 26.1 | 19.10 | 203 | 149.3 |
| | July | 32 | 25.7 | 21.74 | 321 | 133.5 |
| | August | 31.8 | 25.7 | 19.89 | 295 | 128.9 |
| | September | 32.2 | 25.7 | 14.15 | 214 | 117.5 |
| | October | 31.3 | 23.7 | 13.87 | 108 | 116.5 |
| | November | 28.7 | 17.7 | 17.30 | 21 | 88.6 |
| | December | 26.2 | 13.6 | 15.34 | 2 | 70.6 |
| | Site | Alt | Lat | Long | | |
| | Barddhaman | 20 | 23.23 | 87.86 | DOP 25 Nov | LGP 100 d |

| | **Amritsar** | **Barddhaman** |
|---|---|---|
| Growing period (days) | 90 | 100 |
| Days between planting and emergence | 20 | 13 |
| Days between emergence and 100% ground cover | 34 | 32 |
| Days between 100% ground cover and harvest | 36 | 55 |
| DM tuber yield (ton DM/ha) | 2,9 | 9,6 |
| **Fresh tuber yield (ton/ha)** | **14,4** | **47,9** |
| Soil field capacity (mm water / m soil) | 110 | 110 |
| Irrigation point (mm water / m soil) | 50 | 50 |
| Precipitation between planting and harvest | 93 | 36 |
| ETP between planting and harvest | 210 | 198 |
| Accumulated precipitation deficit (mm) | 150 | 167 |
| Soil water reserve (mm) | 30 | 30 |
| Irrigation need (mm) | 120 | 137 |
| **Irrigation need per ton fresh potato (mm)** | **8,31** | **2,85** |

| Station | Month | Temp-Max | Temp-Min | Solar R MJ/M2 | Rainfall (mm/month) | PET (mm/month) |
|---|---|---|---|---|---|---|
| **Gwalior** | January | 23.2 | 7.5 | 13.39 | 20.0 | 60.6 |
| | February | 26.6 | 10.0 | 17.29 | 6.0 | 78.8 |
| | March | 32.9 | 16.0 | 20.71 | 8.0 | 127.8 |
| | April | 38.5 | 22.2 | 24.47 | 3.0.0 | 173.9 |
| | May | 42.5 | 28.0 | 26.02 | 7.0 | 215.4 |
| | June | 40.7 | 30.2 | 23.30 | 69 | 222.4 |
| | July | 34.0 | 26.6 | 21.43 | 274 | 133.8 |
| | August | 31.8 | 25.3 | 15.13 | 282 | 110.7 |
| | September | 32.4 | 24.3 | 12.95 | 173 | 119 |
| | October | 33.2 | 18.0 | 15.21 | 35.0 | 113.7 |
| | November | 29.3 | 10.5 | 12.40 | 3.0 | 75.7 |
| | December | 24.7 | 7.1 | 14.51 | 7.0 | 58.9 |
| | Site | Alt | Lat | Long | | |
| | Gwalior | 180 | 26.224 | 78.179 | | |
| | DOP | 1-Oct | LGP | 110 | | |

| Station | Month | Temp-Max | Temp-Min | Solar R MJ/M2 | Rainfall (mm/month) | PET (mm/month) |
|---|---|---|---|---|---|---|
| **Kanpur** | January | 22.7 | 8.6 | 11.45 | 20 | 67.3 |
| | February | 26 | 11 | 17.43 | 14 | 94.7 |
| | March | 32.7 | 16.2 | 18.19 | 7 | 168.7 |
| | April | 38.2 | 22 | 22.91 | 3 | 225 |
| | May | 41.7 | 27.2 | 21.68 | 6 | 272 |
| | June | 39.9 | 28.7 | 23.70 | 49 | 245.8 |
| | July | 33.7 | 26.6 | 17.16 | 199 | 140.6 |
| | August | 32 | 25.7 | 18.96 | 268 | 117.5 |
| | September | 32.7 | 24.8 | 18.08 | 133 | 128.2 |
| | October | 32.7 | 19.6 | 14.22 | 47 | 130.8 |
| | November | 28.8 | 12.3 | 14.43 | 1 | 90.5 |
| | December | 24.2 | 8.5 | 12.82 | 10 | 75.3 |
| | Site | Alt | Lat | Long | | |
| | Kanpur | 100 | 26.467 | 80.35 | | |
| | DOP | 20-Oct | LGP | 120 | | |

| | **Gwalior** | **kanpur** |
|---|---|---|
| Growing period (days) | 110 | 120 |
| Days between planting and emergence | 10 | 11 |
| Days emergence to 100% ground cover | 27 | 31 |
| Days between 100% ground cover and harvest | 73 | 78 |
| DM tuber yield (ton DM/ha) | 9,3 | 11,7 |
| **Fresh tuber yield (ton/ha)** | **46,7** | **58,6** |
| Soil field capacity (mm water / m soil) | 110 | 110 |
| Irrigation point (mm water / m soil) | 50 | 50 |
| Precipitation between planting and harvest | 73 | 57 |
| ETP between planting and harvest | 202 | 247 |
| Accumulated precipitation deficit (mm) | 161 | 204 |
| Soil water reserve (mm) | 30 | 30 |
| Irrigation need (mm) | 131 | 174 |
| **Irrigation need per ton fresh potato (mm)** | **2,80** | **2,96** |

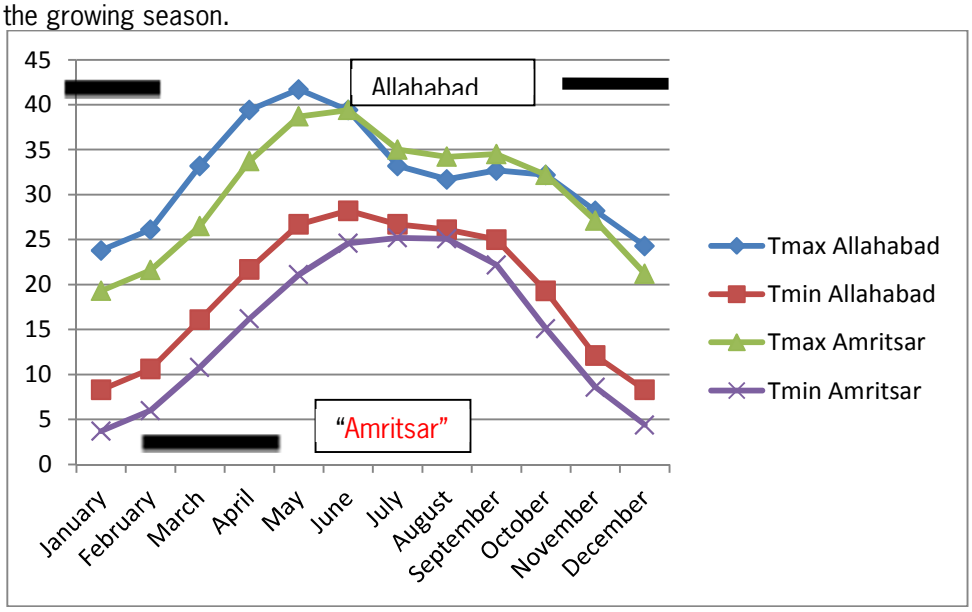
| Station | Month | Temp-Max | Temp-Min | Solar R MJ/M2 | Rainfall (mm/month) | PET (mm/month) |
|---|---|---|---|---|---|---|
| **Kota** | January | 23.2 | 10.6 | 13.61 | 12 | 61.3 |
| | February | 26 | 12.8 | 16.08 | 6 | 71.7 |
| | March | 32.7 | 18.6 | 19.90 | 4 | 116.1 |
| | April | 38.5 | 24.7 | 20.30 | 1 | 163.1 |
| | May | 42 | 29.2 | 22.58 | 8 | 206.9 |
| | June | 39.5 | 28.5 | 23.06 | 63 | 206 |
| | July | 33.5 | 26.2 | 19.29 | 242 | 144.4 |
| | August | 31.5 | 25 | 17.29 | 261 | 120.1 |
| | September | 34.2 | 25 | 18.33 | 91 | 123.9 |
| | October | 34 | 22 | 15.38 | 15 | 128.5 |
| | November | 29.6 | 15.6 | 15.09 | 1 | 77.2 |
| | December | 25.1 | 12 | 13.72 | 3 | 60.7 |
| | Site | Alt | Lat | Long | | |
| | Kota | 340 | 25.11 | 75.79 | | |
| | DOP | 27-Oct | LGP | 110 | | |

| Station | Month | Temp-Max | Temp-Min | Solar R MJ/M2 | Rainfall (mm/month) | PET (mm/month) |
|---|---|---|---|---|---|---|
| **Varanasi** | January | 23.3 | 9.5 | 14.35 | 25 | |
| | February | 26.6 | 12 | 17.69 | 18 | |
| | March | 33.4 | 17.2 | 19.42 | 12 | |
| | April | 38.5 | 22.3 | 23.24 | 3 | |
| | May | 41.5 | 27 | 22.44 | 15 | |
| | June | 39 | 28.2 | 24.69 | 81 | |
| | July | 33.5 | 26.5 | 20.48 | 303 | |
| | August | 32.2 | 26 | 15.78 | 332 | |
| | September | 32.7 | 25.3 | 17.89 | 227 | |
| | October | 32.5 | 20.7 | 15.85 | 44 | |
| | November | 28.6 | 13.3 | 13.19 | 10 | |
| | December | 24.3 | 9.6 | 12.55 | 4 | |
| | Site | Alt | Lat | Long | | |
| | Varanasi | 80 | 25.333 | 83 | | |
| | DOP | 25-Oct | LGP | 117 | | |

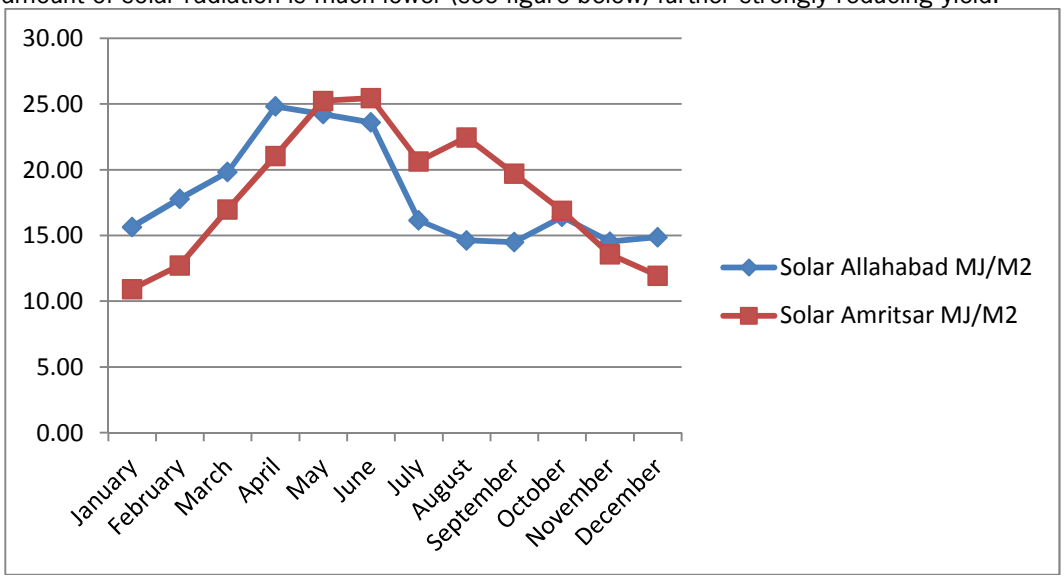
| | **kota** | **Varanasi** |
|---|---|---|
| Growing period (days) | 110 | 117 |
| Days between planting and emergence | 11 | 12 |
| Days emergence to 100% ground cover | 29 | 32 |
| Days between 100% ground cover and harvest | 70 | 73 |
| DM tuber yield (ton DM/ha) | 11,2 | 12,0 |
| **Fresh tuber yield (ton/ha)** | **55,9** | **60,2** |
| Soil field capacity (mm water / m soil) | 110 | 110 |
| Irrigation point (mm water / m soil) | 50 | 50 |
| Precipitation between planting and harvest | 22 | 61 |
| ETP between planting and harvest | 183 | 219 |
| Accumulated precipitation deficit (mm) | 163 | 169 |
| Soil water reserve (mm) | 30 | 30 |
| igation need (mm) | 133 | 139 |
| **Irrigation need per ton fresh potato (mm)** | **2,39** | **2,31** |

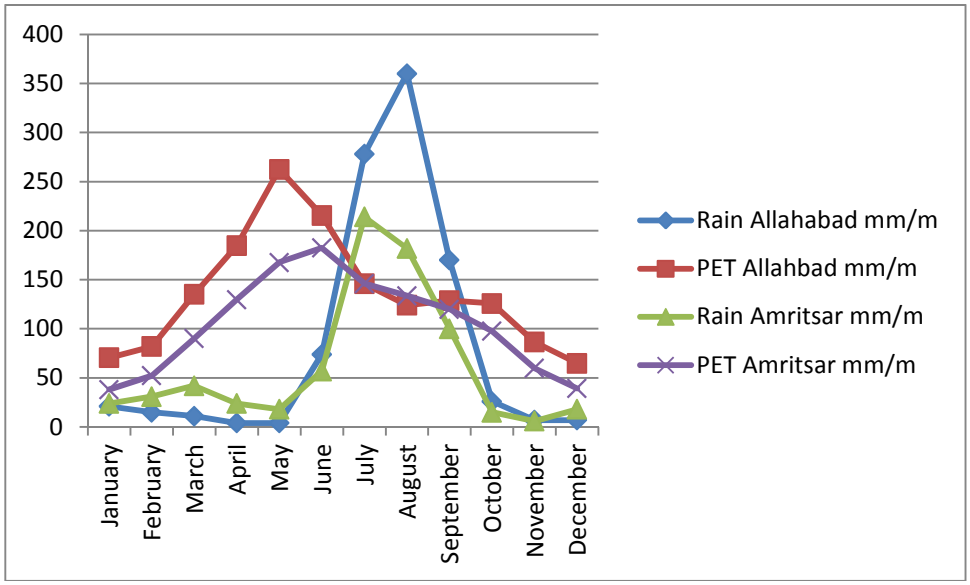
**Summary and discussion**

We noticed that the meteo data for Amritsar supplied by CPRI show temperatures higher than representative for the potato growing areas in the Punjab. As an exercise we continue with those data as they nicely illustrate the power of calculating yielding abilities in contrasting environments.
Allahabad (58.7 t/ha attainable yield) and "Amritsar" (14.4 t/ha) have different climates and different growing seasons. Allahabad's long winter growing season lasts from mid October till mid February (120 days) whereas when in Allahabad the crops are harvested they are planted in Amritsar in a short growing season that starts cold and ends hot. The figure below shows temperatures and the bars show the length of the growing season.

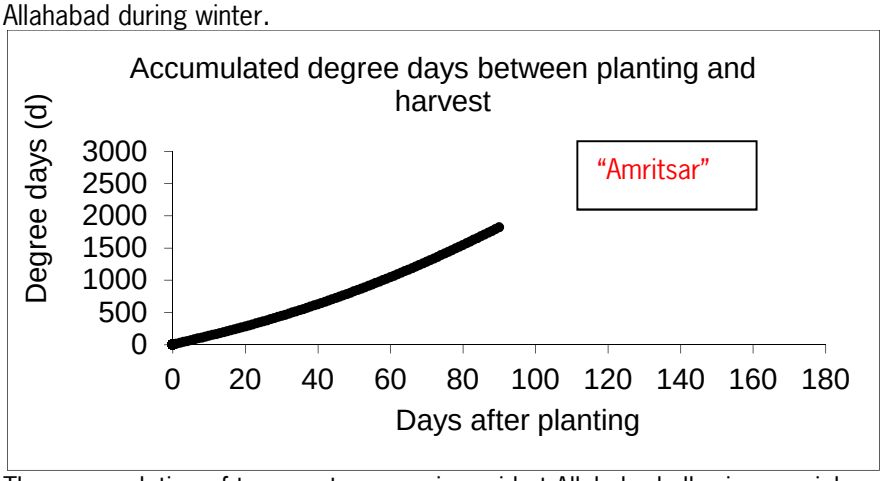



The temperatures at harvest are much lower at Allahabad (26 degrees) than at Amritsar (35 degrees further strongly reducing the yielding ability of the crop as radiation efficiency declines with temperature to arrive at 0 MJ.m$^2$ when Tmax exceeds 33 degrees centigrade. .
Beside the growing season in Amritsar being 30 days shorter than in Allahabad and radiation efficiency being strongly reduced in the second half of the growing season during the season at Amritsar also the amount of solar radiation is much lower (see figure below) further strongly reducing yield.

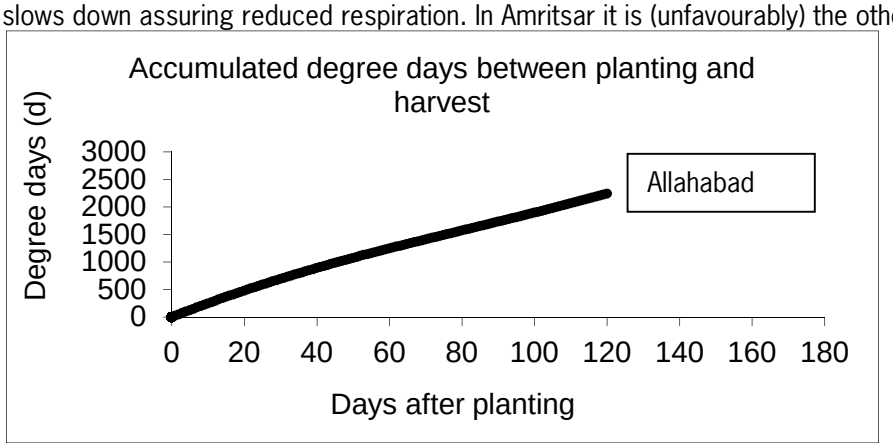


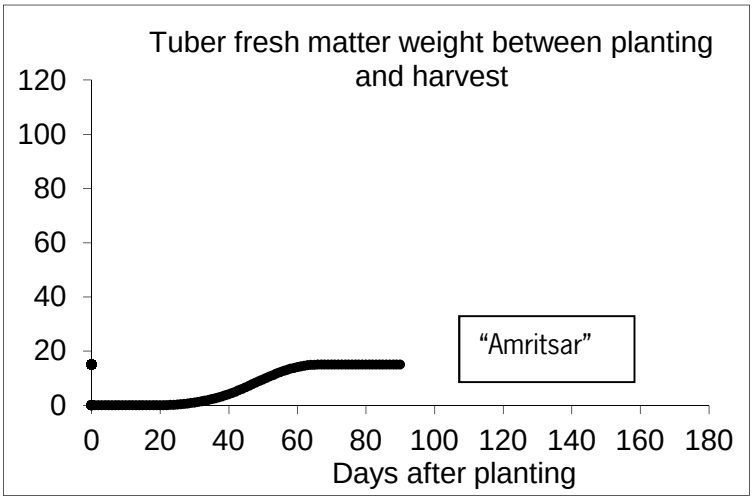



The rainfall and potential evapotranspiration (PET) patterns are similar in both areas as the figure above shows but during the potato cropping season (February – May in Amritsar) daily PET is higher than at Allahabad during winter.

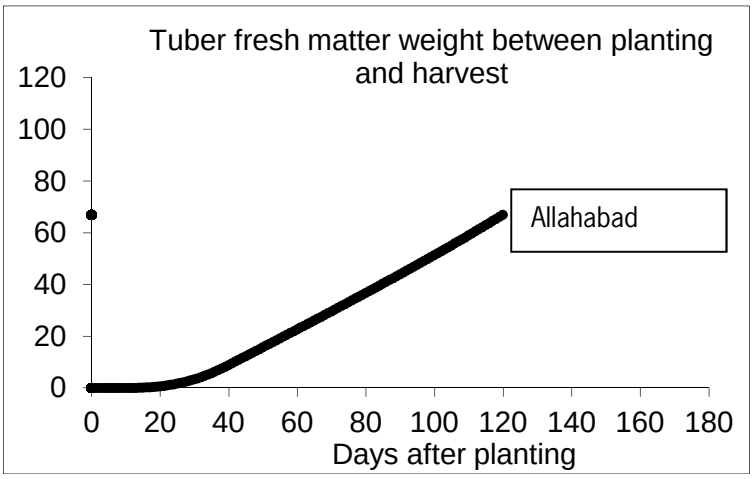



The accumulation of temperature sum is rapid at Allahabad allowing a quick early development and then slows down assuring reduced respiration. In Amritsar it is (unfavourably) the other way around.






These figures show the yield accumulation that continues at Allahabad until harvest whereas at "Amritsar" the second part of the growing season it apparently is too hot for tuber growth.

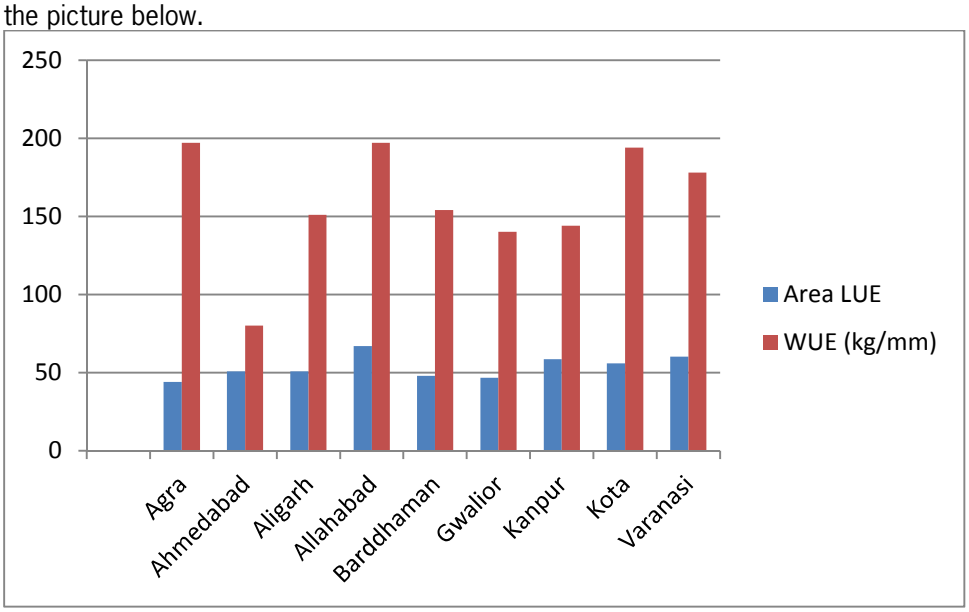



The table below summarizes the calculated attainable yield that varies from Amritsar (14.4 t/ha) to Allahabad with 67.0 t/ha fresh weight. Usually where growers apply fertiliser, irrigation and biocides according to crop needs actual yields vary between 50 and 70% of attainable yields. The table also shows the amount of water needed to apply. This value is 2 x the theoretical "irrigation need" as shown in the tables above. This theoretical values is derived from precipitation deficit and ground cover. Crops, however, suffer well before the available soil water is depleted, hence growers apply about 2 x accounting for leaching and evaporation. The highest amount of irrigation is needed in Ahmedabad (616 mm or 12.1 mm/ton), the lowest amount in Agra (180 mm or 3.9 mm/ton).

| Potato Growing Area | Attainable yield "Land use efficiency" (t/ha) | Irrigation need mm/season | Water use efficiency (kg/mm) |
|---|---|---|---|
| Agra | 44.1 | 180 | 197 |
| Ahmedabad | 50.7 | 616 | 80 |
| Aligarh | 50.8 | 266 | 151 |
| Allahabad | 67.0 | 318 | 197 |
| Amritsar* | 14.4 | 240 | 43 |
| Barddhaman | 47.9 | 274 | 154 |
| Gwalior | 46.7 | 261 | 140 |
| Kanpur | 58.6 | 348 | 144 |
| Kota | 55.9 | 266 | 194 |
| Varanasi | 60.2 | 278 | 178 |

*Apparently not based on meteo data sufficiently representative for the potato growing area in Punjab

Taking out Amritsar the Land Use Efficiencies (LUE) and Water Use efficiencies of the sistes are shown in the picture below.




The lowest yields are calculated for Amritsar due to its short growing as crops are planted late and then temperatures rise rapidly. Yields may be underestimated as the meteorological station may not be placed near potato fields and the night temperatures are quite low compared to other areas possibly compensating somewhat for the high day temperatures.
The water use efficiency was calculated by dividing the nr of kg/ha attainable yield divided by all available water to the crop (mm irrigation need + mm precipitation during the growing season).