Souvenir

Workshop
on
Problems and Prospects of Seed Potato Production Systems in India

September 20, 2013
Central Potato Research Station, Patna

Organized by
Central Potato Research Institute, Shimla
&
Indian Potato Association, Shimla

Workshop
on
Problems and Prospects of Seed Potato Production Systems in India
2013

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Souvenir

Workshop

on

Problems and Prospects of Seed Potato Production Systems in India

September 20, 2013

Venue

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&

Indian Potato Association, Shimla

Editors :

Dr. NK Pandey
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2013

Published by :

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CPRI, Shimla 171 001, Himachal Pradesh, India

Printed by :

Malhotra Publishing House
B-6, DSIDC Complex, Kirti Nagar, New Delhi - 110 015, India
E-mail : mph@vsnl.com

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तारिक़ अनवर
طارق انور
TARIQ ANWAR

सत्यमेव जयते

राज्य मंत्री
कृषि एवं खाद्य प्रसंस्करण उद्योग
भारत सरकार

وزیر مملکت
ایگریکلچر، فوڈ پروسیسنگ انڈسٹریز
بھارت سرکار

MINISTER OF STATE
Agriculture & Food Processing Industries
Government of India

Message

I am pleased to know that Central Potato Research Institute (CPRI), Shimla along with Indian Potato Association (IPA) are organizing a Workshop on **"Problems and Prospects of Seed Potato Production system in India"** on September 20, 2013 at GPRS, Patna, Bihar, the place where the potato research was started in 1949 with the establishment of CPRI. Bihar Sharif has played a pivotal role in production of quality potato seed prior to early seventies. It is therefore in fitness of things that this workshop is being organized in Bihar. In my view, the workshop is timely and necessary keeping in view that the need for good quality potato seed in the country is increasing which is crucial for its further development.

India is the second largest potato producer in the world with a total production of around 42 million tons. Several potato varieties and production technologies were developed and standardized by CPRI. These technologies led to 3.5 times increase in potato productivity in the country. It is a matter of record that more than 70 per cent of total production comes from states of Uttar Pradesh, West Bengal and Bihar. Therefore, there is a need to increase the production level in these states which is possible only when good quality seed is made available to farmers.

I am glad that agricultural scientists, entrepreneurs and other stakeholders are deliberating on important issues related to problems and prospects of seed potato in the country in this Workshop. I am confident that appropriate recommendations will come out of the deliberations.

I appreciate the organizers for organizing this timely meet and wish the event success.

(TARIQ ANWAR)

नरेन्द्र सिंह
Narendra Singh

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दिनांक 05.09.2013

Message

It's a pleasure to learn that CPRI started its journey from Patna, Bihar in 1949. Since then, the institute has contributed immensely to the development of potato in the country by releasing 49 indigenous potato varieties suitable for different regions, popularizing potato in non-traditional areas, providing solutions to all farmers problem and establishing a seed supply chain in the country. The concerted efforts of CPRI made the potato revolution in the country a reality. Now, we are proudly the second largest potato producer in the world. Potato is an important crop in the eastern region and Bihar in particular has made tremendous progress in potato production in recent years.

I am delighted to know that Central Potato Research Institute, Shimla and Indian Potato Association are organizing a Workshop on ***" Problems and Prospects of Seed Potato Production Systems in India"*** on September, 20, 2013 at CPRS, Patna, Bihar. I am sure, this Workshop will help in further spread of scientific knowledge about potato among scientists and other stakeholders and will come out with recommendations for further improvement in quality seed production and its availability to farming community of India in general, and Bihar in particular.

I wish the function a huge success.

Narendra Singh

(Narendra Singh)

5.9.13

Dr. Mangala Rai
Agriculture Advisor to Chief Minister of Bihar.

बिहार सरकार

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MESSAGE

The Central Potato Research Institute started its journey from Patna, Bihar in 1949 and changed the potato scenario of the country. Today this institute is world leader having distinction of developing about 50 improved potato varieties. Suitable technological interventions and establishment of seed supply chain in the country has led to spectacular developments. Now, we are the second largest potato producer after China in the world. The eastern region of the country has more than half of the potato acreage and in recent years this region, particularly, Bihar has made tremendous progress in potato production. During 2012-13, Shri Rakesh Kumar of Sohdih village of Nalanda district could harvest potato to the tune of 108 tonnes per hectare as a world record.

It is heartening to know that Central Potato Research Institute, Shimla and Indian Potato Association are organizing a Workshop on **"Problems and prospects of Seed potato production systems in India"** on September 20, 2013 at CPRS, Patna, Bihar. I hope, this workshop will help in spread of scientific knowledge about potato production and come out with the recommendations for improvement in quality seed production and its availability to the farming community of India in general, and Bihar in particular. I hope, within a year or so, we will be able to have 100 percent tissue culture based potato seed production. Also, aeroponic system of seed production would get much needed impetus. I further hope that the true Potato seed production technology development would receive pin pointed attention.

I wish the function a grand success.

(Mangala Rai)

डा. एन.के. कृष्ण कुमार
उप महानिदेशक (बागवानी)
Dr. N.K. Krishna Kumar
DEPUTY DIRECTOR GENERAL (Horticulture)

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कृषि अनुसंधान भवन- II,
पूसा, नई दिल्ली 110 012
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSANDHAN BHAVAN-II,
PUSA, NEW DELHI 110 012

Message

I am pleased to learn that Central Potato Research Institute, Shimla along with Indian Potato Association is organizing a Workshop on **Problems and Prospects of Seed Potato Production systems in India** on September 20, 2013 at CPRS, Patna, Bihar.

The country witnessed a major potato revolution in the last sixty years. Currently, India is the second largest producer in the world. This was possible mainly due to development of region specific potato varieties and their production technologies by CPRI. During the year 2011-12 the country produced 41.3 million tons of potato from 1.87 million ha. With increasing population, the country faces challenge of providing food and nutritional security to its masses. Being a wholesome food rich in vitamins and minerals, potato will play an important role in this scenario. To achieve a target of producing 69 million tons of potato by 2030, we need to enhance the productivity of potato by way of making quality seed available to the farmers. Lack of quality planting material is a major concern of potato growers in the country, which if met to their satisfaction the potato productivity is expected to increase by 20-25%. Therefore, this workshop is appropriate and timely for addressing the issue related to potato seed.

I am confident that this Workshop will help in identifying problems and issues related to seed potato production in the country and come out with road map to address these issues.

I wish this event a grand success.

N. K. Krishna Kumar

(N.K. Krishna Kumar)

डा. गोरख सिंह
DR. GORAKH SINGH

बागवानी आयुक्त
भारत सरकार, कृषि मंत्रालय
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Dated 27-08-2013.

Message

Horticulture sector in the country is progressing at a rapid pace since it provides better income to the farmers and at the same time helps in crop diversification. Potato is the most important vegetable crop of India. It is a short duration crop and is highly amenable to fit in diverse cropping systems. With Indian population already crossing 120 crore mark, potato has to play an **important** role in providing food and nutritional security to the nation. Therefore, production must be increased by way of increasing productivity through quality seed and better management practices.

It is a great pleasure to learn that Central Potato Research Institute, Shimla along with Indian Potato Association is organizing a Workshop on **"Problems and Prospects of Seed Potato Production systems in India"** on September 20, 2013 at CPRS, Patna, Bihar. This is timely and necessary as the country faces a big challenge of producing 69 million tons of potato by 2030. The Workshop will be a step forward towards solving the problems of farmers in terms of availability of quality potato seed in the country.

I congratulate organizers for organizing this meet and wish the event a grand success.

(Gorakh Singh)

पूर्वी क्षेत्र के लिए भारतीय कृषि अनुसंधान परिषद का अनुसंधान परिसर
ICAR RESEARCH COMPLEX FOR EASTERN REGION
(भारतीय कृषि अनुसंधान परिषद INDIAN COUNCIL OF AGRICULTURAL RESEARCH)
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Dr. B.P. Bhatt, FNAAS
Director

Message

It is a pleasure to know that Central Potato Research Institute, Shimla alongwith Indian Potato Association is organizing a Workshop on ***"Problems and Prospects of Seed Potato Production Systems in India"*** on September 20, 2013 at GPRS, Patna, Bihar.

Potato has been identified as the food for future keeping in view its high production potential and nutritive value. Eastern states have 4.28 million ha area under vegetable production and contribute about 47% of the total vegetable production at the national level. Out of 4.28 million ha area, 1.04 million ha (24.3%) is under potato cultivation with a total production of 20.76 million tonnes. It is one of the promising crops, particularly in West Bengal and Bihar. However, quality seed planting material and lack of technical know-how of potato production technologies are still major bottle necks for potato production, particularly in Eastern States. Hence, ensuring the availability of quality seed to the stakeholders would be a major step forward for potato cultivation.

I hope, the workshop will come out with the recommendations which will be useful for enhancing productivity of potato and thereby benefiting the stakeholders in diverse agroclimatic zones of India.

I convey my best wishes for successful organization of the event.

03/09

(B.P. Bhatt)

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INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSANDHAN BHAWAN-II
PUSA, NEWDELHI-110012

Dr. S.K. Malhotra
Asstt. Director General (Hort.-II)

Message

Potato is a major non cereal food crop consumed by more than a billion people all over the world. In India, as a result of intensive research and development activities undertaken by CPRI during last sixty years, potato area, production and productivity increased manifold. The productivity of potato in country is hovering around 21 tons/ha since last few years. Unavailability of quality potato seed and lack of information about scientific seed production technology among farming community are major problems of potato producers. Therefore, yield gap in potato can be bridged by providing good quality virus free seed potato to farmers and increasing the awareness about modern techniques of seed potato cultivation.

I am happy to know that CPRI, Shimla jointly with Indian Potato Association is organizing a Workshop on **"Problems and Prospects of Seed Potato Production systems in India"** on September 20, 2013 at CPRS, Patna, Bihar. I hope the Workshop will come out with effective recomme'ndations for increasing potato productivity in the country.

I convey my best wishes for success of this National Workshop

4.9.13

(S.K. Malhotra)

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
Dr. Rajendra Prasad Road, Krishi Bhawan, New Delhi
E-mail: adgseedicar@gmail.com

Dr. J.S.Chauhan
Assistant Director General (Seed)

F.No.PA/ADG(Seed)/2013
Dated : 04.09.2013

Message

Availability of quality planting material of any crop is crucial for getting desired production. Although, India has made significant progress in production of quality planting material, yet, it still continues to be the major concern for farmer community. Potato is known as king of vegetables and is consumed world over as a major food crop after rice, wheat and maize. It can play a major role in diversification of cropping system, rural poverty alleviation and food and nutritional security in the country. Being a vegetatively propagated crop, seed is the most important input for potato production which accounts for almost 40 percent of cost of cultivation. Therefore, availability of quality seed potato to farmers at an affordable price is a pre requisite for enhancing potato productivity in the country.

I am glad that Central Potato Research Institute, Shimla along with Indian Potato Association is organizing a Workshop on **"Problems and Prospects of Seed Potato Production systems in India"** on September 20, 2013 at CPRS, Patna, Bihar to address issues related to seed potato production, its supply chain management and availability to farmers. I am sure that this function will come out with recommendations which would benefit the farmers.

I extend my best wishes for success of the event.

(J S CHAUHAN)

Indian Potato Association – A profile

NK Pandey, Brajesh Singh and VK Dua

Indian Potato Association was established in 1974 with its Headquarters at Central Potato Research Institute, Shimla (HP). Dr. (Late) Mukhtar Singh, the then Director, Central Potato Research Institute was the guiding force in conceptualizing the idea and giving it a concrete shape. Since then, the Association has been nurtured by many a stalwarts without whom the Association would not have attained the present heights. In the year 1999, the Indian Potato association crossed a milestone by organizing a Global Conference on Potato at New Delhi to celebrate its 25th Year jointly with Central Potato Research Institute, Shimla that also completed its 50th year. To commemorate the "International Year of the Potato" in 2008, Indian Potato Association organized the Global Potato Conference in New Delhi. The conference was attended by 551 delegates from more than 30 countries including 84 foreign delegates. These conferences were acclaimed as the best organized conferences in both by national and international agencies.

Structure

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

Membership

During the last 39 years, the membership of the Association has grown many folds. At present, it has 975 members of which most of the members are Life members. This is the only scientific association in the country where the farmers outnumber the scientists. Cold store owners, processors, and other industrialists are also registered members of the association.

Mandate

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

value and to conduct publicity/publications and other campaigns through different media for this purpose.

5. Publishing books, reports, summaries of papers and other forms of scientific and technical literature including a newsletter for creating a general consciousness about the potato.
6. Cooperate with other institutions and societies having similar objectives, and fields of activities.
7. Receive grants, subsidies, donations, *etc*. to achieve the outlined objectives.
8. Promote exchange of scientific and other information and develop other means of communication between those engaged in the potato agriculture and the industry and manufacturers of the processed forms of the potato.
9. To foster regional and international co-operation/collaboration in attainment of the outlined objectives.
10. Organize such other activities that are consistent with and in furtherance of these objectives and those, which are decided upon from.

Activities

1. Publishes a scientific journal named as **Potato Journal**, which was formerly known as the **Journal of Indian Potato Association** to promote exchange of scientific information amongst the members.
2. Publishes books on potato for dissemination of new information and technology.
3. Organizes both national and international conferences, seminars/symposia, panel discussion, Farmers' Melas *etc*. from time to time.
4. Confer awards and honours on eminent potato workers, growers, *etc*.

Important Seminars/Symposia Organized by the Association

1. International Seminar on "**Approaches towards increasing the Potato Production in Developing Countries"** at Central Potato Research Station, Jalandhar (Punjab), November 20-23, 1978
2. Panel discussion on "**Problems of potato cultivation in India"** at Central Potato Research Institute, Shimla, June 13, 1986.
3. National Seminar on "**Current facets in potato research"** at Central Potato Research Institute (Campus), December 13-15, 1989.
4. National Symposium on "**Strategies for potato production, marketing, storage, processing**" at Indian Agricultural Research Institute, New Delhi, December 21-23, 1990.
5. National Symposium on "**Potato- Present and Future**" at Central Potato Research Institute (Campus) Modipuram, March 1-3, 1993.
6. Group Discussion on "**Potato based cropping systems**" at Central Potato Research Institute, Shimla during on 30 July, 1994.

7. National Seminar on "Potato **production constraints in low productivity areas**" at Orissa University of Agriculture & Technology, Bhubaneshwar on September 6, 1997.
8. **Global Conference on Potato**, New Delhi, December 6-11, 1999.
9. National Symposium on "**Sustainability of Potato Revolution in India**" at Central Potato Research Institute, Shimla on July 31, 2001.
10. National Symposium on "**Potato Research Towards National Food and Nutritional Security**" at Central Potato Research Institue, Shimla during October 2-3, 2003.
11. National Conference on "**IPR and Management of Agricultural Research**" at NASC, New Delhi during August 27-29, 2005.
12. Symposium on **"Current Perspectives in Potato Research"** at MPUAT, Udaipur on September 11, 2005
13. Symposium on **"A Step Towards Brown Revolution With Potato"** at CPRS, Ootacamund on January 19, 2007.
14. "**Global Potato Confrerence**" at New Delhi during 9-12 December 2008.
15. Seminar on "**Potato in North East**" at CPRS, Shillong during May 8-9, 2009.
16. National consultation on "**Production of Disease Free Quality Planting Material Propagated through Tubers and Rhizomes**" at CPRIC, Modipuram during 4-5 March, 2011.
17. National Conference on "**Genomics for Sustainable Food and Nutritional Security**" at CPRI, Shimla on 26th November 2011.
18. National consultation on "**Potato Research and Development: Way Forward**" at OUAT, Bhubaneshwar, Orrisa on 26th September 2012.

Honorary Fellows

The Association has so far conferred Honorary Fellowships on 22 distinguished potato workers/growers for their outstanding contributions in the field of potato research and development. They are:

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

17. Dr. Mukhtar Singh *
18. Dr. GS Shekhawat*
19. Dr. PK Gupta
20. Dr. KV Raman
21. Dr. Pamela Anderson (Peru)
22. Dr. John Bradshaw (UK)

**deceased*

Distinguished Fellows

The Association elects distinguished fellows from among its members. So far 42 scientists have been elected as Distinguished Fellows of the Association. They are:

Dr. SK Bhattacharyya (1994)
Dr. KC Dubey (1994)
Dr. SM Paul Khurana (1994)
Dr. JT Nankar (1994)
Dr. ML Pandita (1994)
Dr. KP Sharma (1994)*
Dr. GS Shekhawat (1994)*
Dr. RA Singh (1994)
Dr. RP Singh (1994)
Dr. SC Verma (1994)
Mr. SS Shivalli (1994)
Dr. NM Nayar (1994)
Dr. MS Rana (1994)
Dr. RC Sharma (1995)
Dr. KD Verma (1995)
Dr. UC Sharma (1996)
Dr. PC Gaur (1996)
Dr. AK Singh (1997)
Dr. SNS Srivastava (1997)
Dr. GS Kang (1998)
Dr. NP Sukumaran (1998)
Dr SM Verma (1999)
Dr BL Barua (1999)
Dr. Jagpal Singh (1999)*
Dr SS Lal (2000)
Dr. KSK Prasad (2000)
Dr. BP Singh (2001)
Dr. SK Pandey (2001)
Dr. KC Sud (2002)
Dr. VK Chandla (2002)
Dr. PS Naik (2003)
Dr. KC Garg (2003)
Dr. SV Singh (2004)
Dr. RB Singh (2004)
Dr. JS Minhas (2005)
Dr. MS Kadian (2005)
Dr. KR Dhiman (2006)
Dr. SC Khurana (2006)
Dr. RS Marwaha (2007)*
Dr. Jai Gopal (2007)
Dr. SK Chakrabarty (2008)
Dr. R Ezekiel (2009)
Dr. RK Arora (2009)
Dr. SP Singh (2009)
Dr. NK Pandey (2010)
Dr. SP Trehan (2010)
Dr. Ashiv Mehta (2010)
Dr. VK Dua (2011)
Dr. Brajesh Singh (2011)
Dr. RK Singh (2011)

** deceased*

Awards

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

1. IPA Medal for the Best Paper published in the Journal of the Indian Potato Association now known as Potato Journal.
2. Best Poster Award.
3. Ramanujam Memorial Award Lecture.
4. IPA-Kaushalya Sikka Memorial Award
5. IPA-Chandra Prabha Singh Young Scientist Award
6. Grower of the Year Award.

Publications

1. Potato Journal – Half Yearly.
2. Books/ Proceedings.

List of Books/Proceedings

1. **Potato in Developing Countries** Proceedings of International Seminar "Approaches Towards Increasing the Potato Production in Developing Countries" held at Central Potato Research Station, Jalandhar, November 20-23, 1978.
2. **Current Facets in Potato Research** Proceedings of the National Seminar held at Central Potato Research Institute Campus, Modipuram, December 13-15, 1989.
3. **Strategies for Potato Production, Marketing, Storage and Processing** Proceedings of the National Symposium held at Indian Agricultural Research Institute (IARI) New Delhi, December 21-23, 1990.
4. **Potato: Present and Future** Proceedings of the National Symposium held at Central Potato Research Institute Campus, Modipuram March 1-3, 1993.
5. **Summary Proceedings – Global Conference on Potato**
6. **Potato, Global Research & Development Vol. I and II** Proceedings of the Global Conference on Potato, New Delhi, December 6-11, 1999.
7. Souvenir & Abstracts of the Conference on "**Processing and Export Potential of Potatoes within Asia**", 10 March 2003, Modipuram, India.
8. **Souvenir** of the **Symposium on "Potato Research Towards National Food and Nutritional Security"** and **Dr. S. Ramanujam Birth Centenary Celebrations,** Shimla, October 2-3, 2003.
9. Souvenir of International Potato Conference and Fest-04 on "**Processing and Export Potential of Indian Potatoes**", 13 March 2004, Modipuram, India.

10. Souvenir of the "**National Conference on IPR and Management of Agricultural Research**", New Delhi, 27-29 August 2005.
11. Souvenir of the "**Global Potato Conference 2008**", New Delhi, December 9-12, 2008.
12. Souvenir of the "**Seminar on Potato in North East**", May 8-9, 2009, Shillong.
13. Sourvenir of the National consultation on "**Potato Research and Development: Way Forward**", 26th September 2012, OUAT, Bhubaneshwar, Orrisa.

Year	President	Vice President	Secretary	Joint Secretary	Treasurer	Editor-in-Chief	Business Editor
1974 1975	Mukhtar Singh	BS Jogi; Kirti Singh; Hari Kishore; US Kang; HN Singh; A Kelman	LC Sikka	GS Shekhawat	VM Khanna	BB Nagaich	SC Verma
1976	BB Nagaich	BS Jogi; Kirti Singh; US Kang; Kirti Singh; Niranjan Prakash; JS Niederhauser	LC Sikka	GS Shekhawat	VP Malhotra	BB Nagaich	SC Verma
1977	BB Nagiach	LC Sikka; SN Bhargava; Daljeet Singh; MD Upadhya	JS Grewal	GS Shekhawat	SM Paul Khurana	BB Nagaich	SC Verma
1978	BB Nagaich	LC Sikka; SN Bhargava; Daljeet Singh; MD Upadhya	JS Grewal	GS Shekhawat	SM Paul Khurana	SB Lal	NP Sukumaran
1979	SB Lal	MS Rana; JS Grewal; HS Sangha; SN Bhargawa	GS Shekhawat	JS Gill	SM Paul Khurana	BB Nagaich	SP Trehan
1980	BB Nagaich	BL Barua; SL Dubey; AK Singh; A Naik; Guru Amarjit Singh; DS Singh	GS Shekhawat	SS Grewal	SM Paul Khurana	KP Sharma	MS Virk
1981 1982	BB Nagaich	JS Grewal; RN Khanna; JK Maheshwari; M Shyam; DS Singh; SM Verma	PC Gaur	SK Pandey	SK Bhattacharya	KP Sharma	MS Virk
1983 1984	JS Grewal	Jagpal Singh; BN Singh; MD Upadhya; SS Saini; CL Khushu; SP Singh	SM Paul Khurana	PS Dahiya	RA Singh	GS Shekhawat	SM Paul Khurana
1985 1986	JS Grewal	Jagpal Singh; BD Sharma; OM Bombawala; BS Sangar; SG Phadtare; JT Nankar	SK Bhattacharaya	SS Misra	VK Chandla	SM Paul Khurana	MN Singh
1987 1988	KP Sharma	PC Misra; UC Sharma; MP Srivastava; Nepal Singh; Janardan Jee; AV Gadewar	RA Singh	RK Birhman	HC Sharma	SK Bhattacharya	BP Singh
1989 1990	JS Grewal	GS Shekhawat; Laxman Lal; Jagpal Singh; SS Saini; Janardan Jee; KS Krishna Prasad	RA Singh	VK Chandla	MC Sood	SK Bhattacharya	BP Singh
1991 1992	JS Grewal	GS Shekhawat; UC Sharma; GS Kang; Jagpal Singh; VS Khushwah; RK Arora	VK Chandla	MK Dhingra	SR Yadava	SK Bhattacharya	BP Singh
1993 1995	GS Shekhawat	RA Singh; UC Sharma; GS Kang; KD Verma; Janardan Jee; Gowada P Madappa	SK Pandey	R Chandra	KC Sud	SM Paul Khurana	BP Singh
1996 1997	SM Paul Khurana	RC Sharma; Kamla Singh; JP Singh; Jagpal Singh; R Sinha; KSK Prasad	BP Singh	Shiv Kumar	RK Birhman	GS Shekhawat	SS Lal
1998 1999	GS Shekhawat	PC Gaur; BK Sharma; IP Chaubey; Janardhan Jee; PM Govindakrishnan	BP Singh	KC Sud	SR Yadav	SM Paul Khurana	SK Pandey
2000 2001	GS Shekhawat	PS Dahiya; SP Trehan; SV Singh; RP Rai; SS Shivalli	PS Naik	KC Sud	SR Yadava	SM Paul Khurana	SK Pandey
2002 2003	SM Paul Khurana	Shiv Kumar; Kamla Singh; DS Uppal; Raj Pal Singh; BK De; TA Joseph	KC Sud	NK Pandey	JS Minhas	SK Pandey	Brajesh Sigh
2004 2005	SM Paul Khurana	VK Chandla; YP Sharma; RK Arora; BP Singh; BK Mandal; TA Joseph	JS Minhas	SK Chakrabarti	VK Dua	SK Pandey	Brajesh Singh
2006 2007	SK Pandey	MC Sood; YP Sharma; RS Marwaha; BP Singh; VS Verma; K Manorama	JS Minhas	SK Chakrabarti	VK Dua	Jai Gopal	Brajesh Singh
2008 2010	SK Pandey	JS Minhas; SV Singh; RS Marwaha; RP Rai; S Ramani; SS Shivalli	SK Chakrabarti	VK Dua	NK Pandey	Jai Gopal	Brajesh Singh
2011 2012	BP Singh	PS Naik; Ashiv Mehta; AK Somani; RP Rai; SS Shivalli	NK Pandey	VK Dua	Brajesh Singh	PM Govindakrishnan	Rajesh K Rana
2013 2014	BP Singh	SS Lal; JS Minhas; SK Kaushik; Manoj Kumar; KM Indiresh	NK Pandey	Brajesh Singh	VK Dua	PM Govindakrishnan	Rajesh K Rana

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Seed Production in India- An overview

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Introduction

Potato is one of the world's most important non-cereal horticultural food crop. India has taken a giant leap in terms of potato area and production since independence. Compared to 1949-50, the year of establishment of CPRI, when the total production was 1.54 million tones from an area of 0.234 million ha, we now (2011-12) produce 41.328 million tones of potato from1.89 million hectare area. Currently the national average productivity of potato is 22.07 tones/ha with highest productivity of 29.68 t/ha in Gujarat followed by 28.92 t/ha in West Bengal. As compared to potato production scenario in India during 1949-1950 there has been a phenomenal increase in area, production and productivity over the last six decades (Fig. 1). In terms of area, India ranks third in the world after China and Russian Federation and second in production after China (Fig.2). As of now, country is well placed to meet the emerging challenges for diversifying the potato production and stabilizing its market.

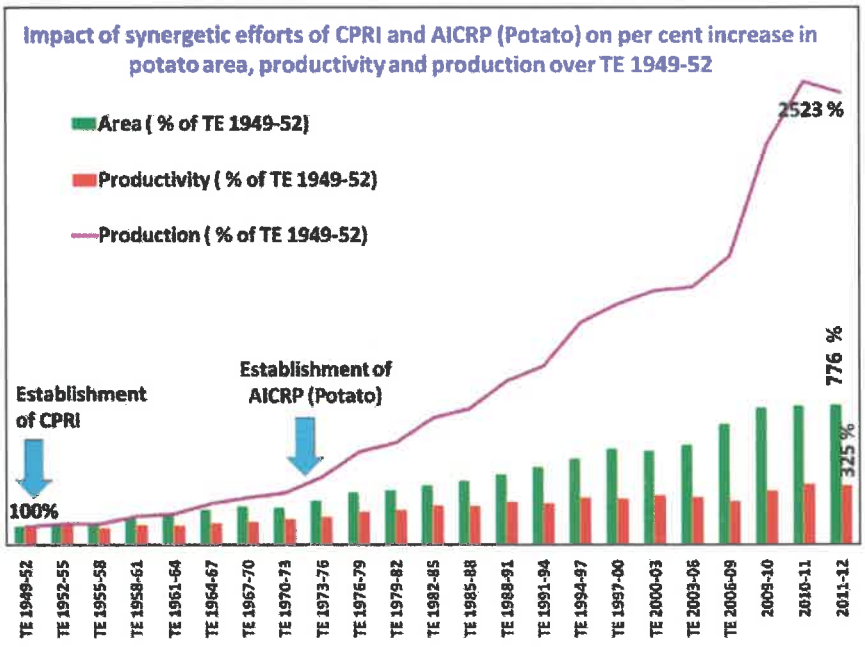

Fig. 1. Percent increase in area, production and productivity of potato in India since 1949

Potato being largely a vegetatively propagated crop, it is subjected to large number of seed-borne diseases responsible for degeneration of seed stocks over the years. Potato virus Y alone may cause 61% crop loss in the third year of cultivation. It is therefore imperative to use good quality seed for economic production. Till 1935, the seed potato was being imported from various European countries on yearly basis, but during 2nd World War, European countries put a blanket ban on the export of potato seed to India. To meet this exigency, Imperial Agriculture Research Institute started potato breeder seed production

scheme at Shimla and Kufri during 1935. It was the beginning of seed potato industry in the country. However, there were several problems associated with hill seed these include i) It is not of right physiological age for use in the plains, ii) It carries soil and tuber-borne pathogens not often found in the plains, iii) long distance transport and, iv) area in hills was insufficient to cater to the requirement of the whole country. Due to dormant nature of the hill seed, either the dormancy was broken artificially using GA and thiourea or the system of late planting, some where in last week of December, was adopted to grow late winter or spring crop of potato. But the spring crop was exposed to high population of aphids leading to very high viral infestation resulting in poor productivity in the subsequent generations. As mentioned above, the area under potato was quite marginal in the hills. It was therefore not possible to feed large area in the plains. Therefore, intensive survey was carried out through out the Indo-Gangetic plains to find out vector free period/low vector period suitable for potato seed production and multiplication. This laid the foundation of development of "seed plot technique" in 1959 which helped production of good quality seed in the plains so as to meet the bulk seed requirement for ware potato production in the sub-tropical plains. Seed Plot Technique which was formalized in 1968 not only benefited our farmers but also saved millions of rupees on foreign exchange which would have gone for purchase of costly seed from foreign countries.

Seed requirement

At present the country has an area of approximately 1.89 million ha under potato and as such requires about 4.73 million tones of quality seed at the rate of 2.5t/ha to achieve 100% seed replacement rate. Every year the desirable seed replacement rate of 25% is must to get good production and productivity of potato in the country. However, the current average seed replacement rate of country in potato is much below than the desirable seed replacement rate (25%). Currently, about 2.96 million tones (8.5%) of the total potato production are being used as seed. Central Potato Research Institute is producing only about 2600 tones of breeder seed per annum. Having a huge gap between supply and demand of late, Private Sector has entered into potato seed sector in a big way and it is hoped that this gap will be filled in due course of time. CPRI has also started seed production programme in public/private mode under MoU for augmentation of seed chain in the country. In potato cultivation, potato seed is most expensive input accounting for 40 to 50 percent of the production cost. Moreover, a high rate of degeneration causes the seed to deteriorate after a few multiplications. Since the eastern, north-eastern, Deccan and South western parts of the country, having warmer climatic conditions, are not suitable for traditional quality seed production barring few locations, the farmers of

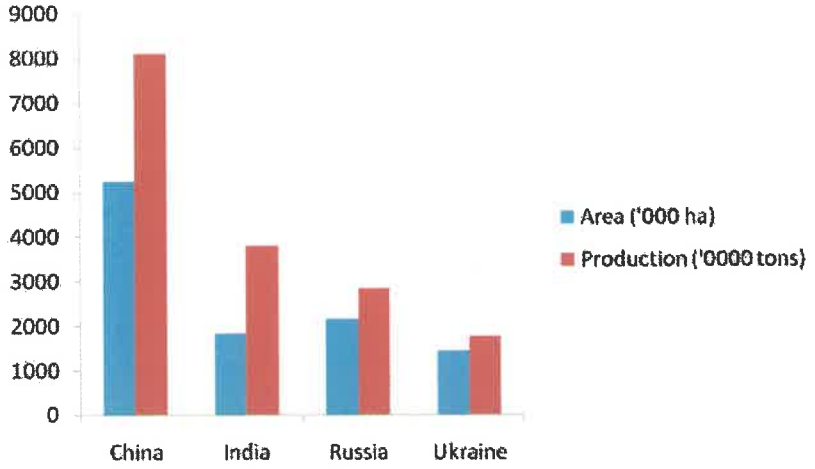

Fig. 2. India ranks second in production and third in area in the world (2009-2011)

these areas have to buy the seed potato from northern India. This is not a happy situation. There is an urgent need to explore possibilities of seed production in non traditional areas using modern technique. CPRI is on its way in this direction.

Table 1. Suitability of regions for seed production

State	Zone	Type of seed	Remarks
Himachal Pradesh	North high hills	Nucleus, Breeders, Foundation and Certified seed	Low aphids during cropping season and no serious soil and tuber borne disease and pests
Jammu & Kashmir	Northern high hills	Breeders seed, Foundation and Certified seed	Low aphid infestation
	Plains	Foundation and Certified seed	High population of aphids
North-Eastern states	North-eastern high and mid hills	Foundation and Certified seed	High population of aphids and infestation of brown rot
	Darjeeling region	Seed for local use	Wart disease
Punjab, Haryana, UP, MP, Bihar	Indo-Gangetic plains	Nucleus, Breeders, Foundation and Certified seed	Low aphids during October to mid January and no serious soil and tuber borne diseases
West Bengal, Orissa, eastern MP	North eastern plains	Foundation and certified seed	High population of aphids and bacterial wilt
Maharashtra, Karnataka, Andhra Pradesh	Plains and Plateau region	Seed for self use	High population of aphids and brown rot incidence
Tamil Nadu	Nilgiri hills	Seed for self use	Presence of cyst nematode and brown rot incidence

Seed Production and supply before 1970

Although more than 15 aphid species colonize potato crop but amongst them *Myzus persicae* and to some extent *Aphis gossypi* are the major vectors responsible for spread of viral diseases in potato. In hills, these are either absent or there population is below critical level during the crop season due to cool climate. Therefore, hills became popular for the production of quality seed in India. Due to this, the demand for hill seed increased in the sub-tropical plains. Seed from Northern hills had higher productivity than the seed produced in spring in the plains. As a result, a channel of seed movement from hills to plains was established.

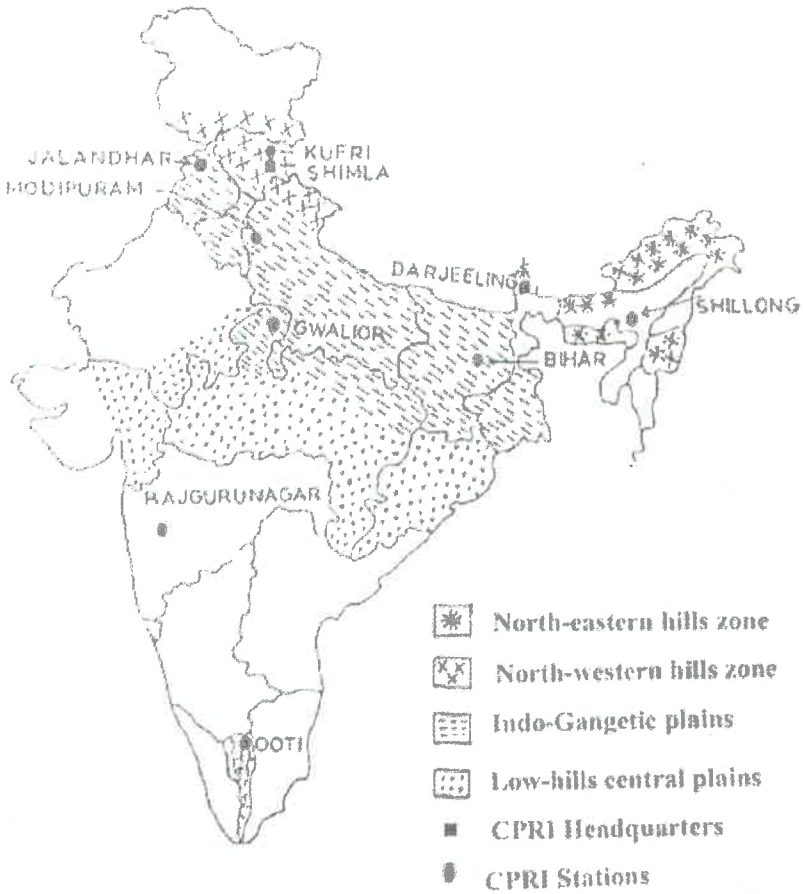

Fig. 3. Seed production scenario after 1970

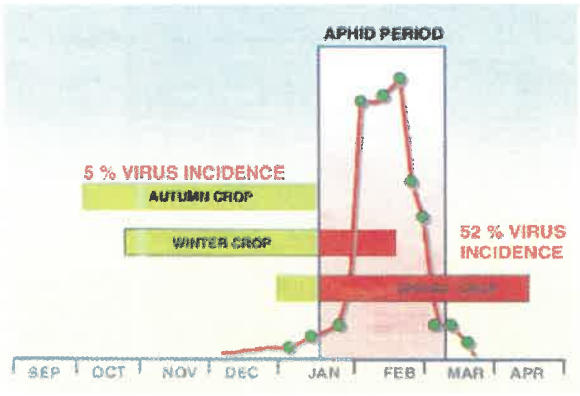

Fig. 4. Aphid population build up in Sub-tropics

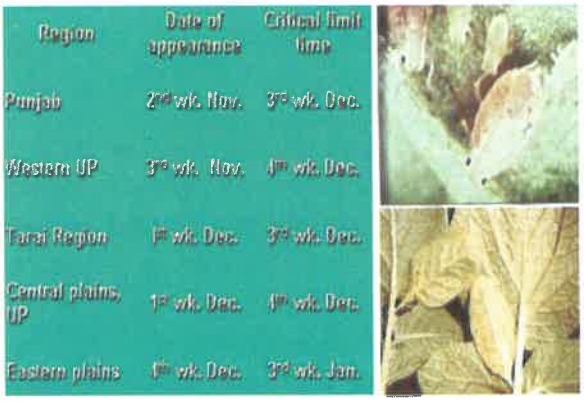

Fig. 5. Appearance and build up of aphids in Indo-Gangetic plains

Aphids crossed their critical limit (20 aphids per 100 compound leaves) in these regions only after last week of December in North Western plains and second week of January in North-Eastern plains (Fig. 4 & 5). Based on the survey, Central Potato Research Institute developed a technique called "seed plot technique" during 1968. The important components of seed plot technique are depicted in fig. 6.

Fig. 6. Components of seed plot technique

The main principle of this technique is based on growing of seed potato crop using healthy seed during low aphid period from October to first week of January coupled with integrated pest and disease management, roguing and dehaulming the seed crop during the last week of December or second week of January before aphids reach the critical level. This technique opened a window in sub-tropical plains for production of quality seed. The seed production could be taken up in larger areas under sub-tropical plains comprising of Punjab, Haryana, U.P., Bihar and parts of M.P. Farmers could get seed of right physiological age at the time of planting, as it does not have any dormancy problem. For raising seed crop, avoiding build up of soil-borne pathogens by adopting of 2-3 years crop rotation is essential. The schedule of planting, dehaulming and harvesting for different regions is described under table 2.

Table 2. Seed crop planting, dehaulming and harvesting schedule for different regions

Location	Planting	Dehaul ming	Harvesting
Punjab and Haryana	Oct. 7	Dec. 31	Jan. 15
NW and central plains	Oct. 15	Jan. 10	Jan. 25
Eastern UP and MP	Oct. 31	Jan. 15	Jan. 31
Bihar, WB and Orissa	Nov. 7	Jan. 20	Jan. 31

Irrigation should be withheld 7 to 10 days before haulms killing i.e. third week of December in North-Western plains and first week of January in North-Eastern plains. In the seed crop, haulms should be killed before aphids reach its critical level. Haulms can be killed by sparing gramoxone @ 2.5 to 3.0 l ha^{-1} or manually by cutting. Exposed tubers should be covered with soil immediately after haulms killing and re-growth of the haulms should be checked on regular basis till harvest.

Conventional breeder seed production system

Taking advantage of seed plot technique, a well organized strategy for production of breeder's seed was envisaged after 1970 through clonal selection and tuber indexing and stage-wise field multiplication of healthy indexed tubers in subsequent four generations. In this system, elite tubers are first individually indexed against PVX, PVS, PVM, PVA, PVY and PLRV using ELISA. Tuber indexing is a process of testing the selected tubers for virus freedom by growing their eye plugs under net house/ glass house. Clonal selection is done from stage-I both in hills as well as in plains. Hill tubers are indexed in the plains in winter in one or two shifts i.e. one from November to January and another from January to March as the environmental conditions are favourable in plains than in hills. During winter, indexing can also be done in the hills under controlled conditions in the glass houses. In the plains, tubers are indexed at the station themselves after dormancy breaking from February to April through leaf ELISA or in September by sprout ELISA. For this, an eye plug is scooped next to the crown end from each of four selected tubers of each clone (1 cm dia and 1.5 cm length) with a specially designed knife and the counterpart tubers are retained in a group separately. The knife is sterilized with spirit after scooping each eye to avoid transmission of viruses and bacteria to other healthy tubers/clones. The scooped dormant eye plugs (clone-wise) are treated with 1 ppm GA_3, 1 per cent thiourea and 0.2 per cent mancozeb solution for 1 h. The eye plugs are subrized in shade and all the four eye plugs of each clone are bagged in 10 x 5 cm perforated polythene bags along with label. The eye hole of counterpart tubers is dusted with dry cement or ash + mancozeb mixture to avoid microbial infection. Four tubers of one clone are stored in1 kg capacity perforated polythene bag or arrange serially in wooden/plastic crates and stored in country stores in the hills from November to March and under cold stores from March to September in plains. The earthen pots (4" dia earthen/plastic) are filled with sterilized soil plus FYM mixture (1:1) and arrange serially in a group of four pots in the glass house and plant one eye plug per pot without damaging the sprout (Fig. 7). The ideal temperature for plant growth and virus multiplication is 20-25°C. The plants for virus freedom by ELISA are tested after 6 to 7 weeks planting or at 6 to 8 leaf stage as per the procedure. Even if any plant out of four eye plugs in a clone is found infected with virus during testing, all the counterpart indexed as well as their un-indexed sister counterpart tubers are to be rejected. The disease free tubers obtained during indexing are used for production of nucleus, breeder, foundation and certified seed as per procedure described under figure.

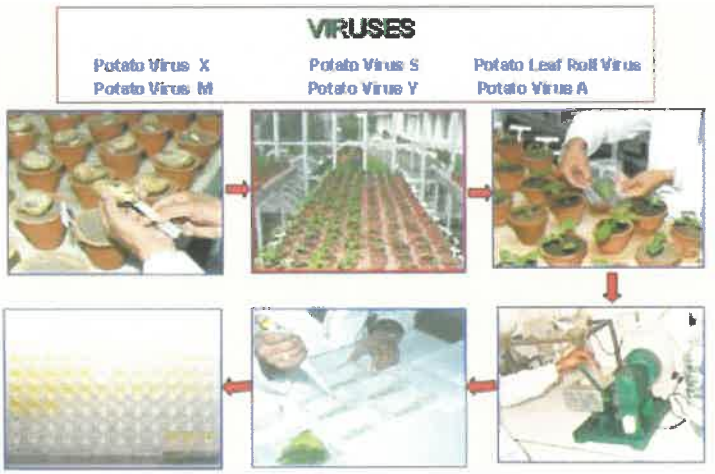

Fig. 7. Tuber indexing by ELISA

The breeder seed produced by CPRI is supplied to various state Govt. organizations for further multiplication in three more cycles' viz., Foundation-1, Foundation-2 and Certified seed as per seed act.

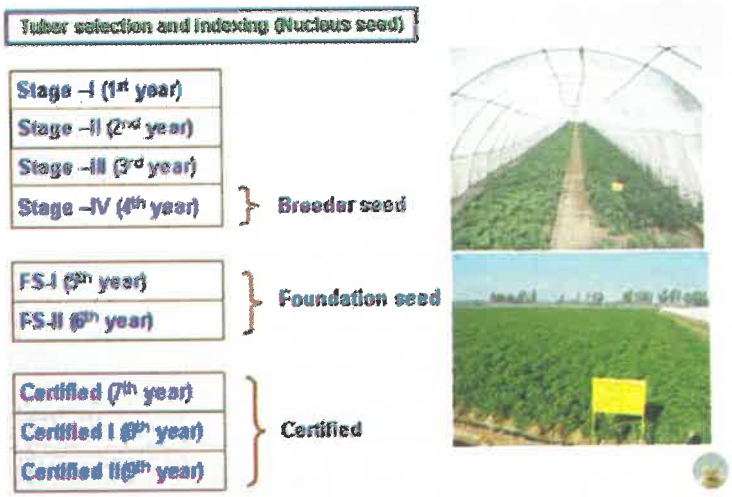

Fig. 8. Different stages in seed production

The conventional system although is very robust and easy to adopt but it has several limitations like, i) low rate of multiplication ii) requires more number of disease free propagules in the initial stage iii) development of 100% healthy seed stock from infected material is slow and time taking iv) progressive accumulation of degenerative viral diseases in each field exposure and, v) many field multiplications of initial disease-free material (7 years). To overcome these limitations Central Potato Research Institute is gradually shifting from conventional system of seed production to hi-tech seed production.

High-tech system of potato seed production

High tech potato seed production is based on tissue culture technique. This technique enables large scale multiplication of healthy plants round the year which is not possible under conventional system. This system is also aimed at reducing the field exposure and thereby minimizing the accumulation of viruses in the seed stocks. This system can be further sub-divided into three system viz. seed production based on (i) microplants (ii) micro-tubers and (iii) aeroponics.

(I) Microplants-based seed production system

The mother tuber(s) of a known variety should be free from all viruses and seed-borne diseases. The mother plants raised from mother tubers should be tested by all possible methods for virus freedom before initiating *in vitro* culture. These include, ELISA, ISEM, PCR, NASH etc. The virus-free stocks are multiplied through nodal cuttings on semisolid MS medium in culture tubes (25 x 50 mm) or in any other suitable containers following the standard procedure upto 10-12 cycles. *In vitro* plantlets are then hardened for 8-10 days under appropriate conditions. During hardening, three to four week old microplants are transferred to protrays filled with sterilized peat moss. The microplants can be planted in protrays with roots or without root (cuttings). For planting with root, the media sticking to the root should be properly washed off. For planting without root, the microplants should be cut just above the medium and cut end should be dipped in soft wood rooting hormone powder if required. After transplanting, drenching should be done with mancozeb (0.2%) solution. Protrays are transferred to the growth chambers and kept in dark for 48 h and subsequently under light (16 h photoperiod) for 2-3 days. Once the plantlets are established in protrays, these protrays are transferred to hardening chamber maintained at 27ÚC for 10-15 days. The hardened plantlets should be removed from protrays along with peat moss and

transplanted on nursery beds in mixture of soil, sand and FYM in rows at appropriate spacing under insect-proof net house conditions. Five per cent of the plants are tested by ELISA. The seed produced from the microplants is known as minitubers (G-0). Minitubers weighing >1 g are planted in Generation-1 in the field during next season. The produce of G-1 is further multiplied in the field for one more time (G-2). The G-2 produce is sold as breeder seed.

Fig. 9. High-tech Seed Potato Production

(ii) Microtubers-based seed production system

The microtubers are induced on the microplants in controlled conditions. For inducing the microtubers, 3-4 weeks old microplant shoot cutting are transferred into 250 ml conical/erlenmeyer flasks or culture bottles containing 25-35 ml liquid medium. Cultures are then incubated at 25ÚC and 16 h photoperiod in the culture room. Medium is decanted and changed with tuber induction medium. The plants are then incubated in dark for 2-3 months for production of microtubers. The microtubers are hardened and used for raising seed crop under net house.

(iii) Aeroponic based seed production system

There is a tremendous scope to increase healthy seed production by adopting aeroponic technology where increase in multiplication rate from 5:1 to 50:1 can be achieved. Aeroponics is the process of growing plants in an air mist environment without soil or an aggregate medium. We do not need any excess area for aeroponic based healthy seed production. Only one percent of conventional water usage is required which is basically recycled water. It is the ideal technology for cost-effective production of quality seed in the present era. In this system, the roots of the plant are grown in complete darkness in lightproof sealed box or container where the roots are intermittently supplied with nutrient solution in mist form. The nutrient solution is continuously re-circulated through the system and monitored and amended whenever necessary. The top portion of the plant is exposed to the open air and a light source. It

prevents exposure of plantlets to unfavourable soil conditions and the minitubers harvested from this system will be free from soil-borne pathogens. Desired size of minitubers can be harvested sequentially and this could reduce the cost of minituber production. The details of this system are given under chapter entitled "Soilless production of potato minitubers".

Important diseases of seed crop

Viral diseases

More than three dozen viruses infect the potato crop throughout the world. Out of these, about a dozen of viruses occur in India, but a number of exotic viruses are not prevalent/ present in India and therefore, plant quarantine should be strictly adopted against such viruses in order to prevent their introduction. In potato seed production, only seven viruses viz., PVX, PVS, PVY, PVA, PVM, PLRV and PALCV are economically important. Recently potato stem necrosis caused by peanut bud necrosis virus is also encountered in central India and is becoming a menace in early planted seed potato crop in Madhya Pradesh and Maharashtra when the temperatures are high during October. It causes foliar infection up to 80 percent which leads to considerable yield loss. However, this virus is not carried in the tubers. The viruses differ in nature and morphology and cause variable symptoms in the host plant.

1 Potato virus X (PVX): The virus is mechanical/contact transmitted. Symptoms appeared as mild to moderately severe perceptible mottling of leaves with light to dark green patches interspersed with normal green colour. Sometime stunted plant growth with chlorosis. Latent in many varieties.

Potato Virus M

2. Potato virus S (PVS): The virus is mechanical/contact transmitted. Mild imperceptible mottling of leaves with light green patches interspersed with veinal green colour. Usually latent.

3. Potato virus M (PVM): The virus is transmitted by contact as well as non-persistently by aphids. Mild mosaic/mottling of young leaves and upward rolling of upper leaves with wavy margins, slight leaf chlorosis.

4. Potato virus A (PVA): Non-persistently transmitted by aphids. Mosaic faint mottling, sometimes leaf distortions, top necrosis in some varieties, rarely rugosity, shiny leaves.

Potato Virus Y

5. Potato virus Y (PVY): Non-persistently transmitted by aphids. Mottling of leaves with light to dark green patches interspersed with normal green colour and severe mosaic. Production of necrotic spots and veinal necrosis followed by leaf drop streaks. Rugosity, twisting of leaves with slight inter-veinal cuppings.

6. Potato apical leaf curl virus (PALCV): The virus is transmitted by white-fly. In severe cases it can be identified easily, but such symptoms are expressed only when the concentration of virus is very high. However, in many cases the symptoms are recovered as the maximum temperature fall below 28ÚC. If the virus concentration is less it produces leaf rolling, which will be just like symptoms caused by Potato virus M.

7. Potato leaf roll virus (PLRV): The virus is transmitted by aphid in persistent manner. Varying degree of rolling is observed. Lower leaves roll first followed by upper ones. The lower leaves become leathery with bronze margins and on pressing, between fingers they give rustling sound. Stiffness of older leaves.

8. Potato acuba mosaic virus: It is transmitted by aphid. Symptoms are observed in old varieties, bright yellow spots/patches on old leaves. Stunting of the plants.

Potato apical Leaf curl virus

9. Rugose mosaic (X+Y): It is due to combined infection of viruses X and Y. Plants show severe mosaic and rugosity of leaves and stunted plant growth. Leaves curl upward while lower leaves show yellowness and necrosis.

10. Crinkle (X+A): Caused by combined infection of viruses X and A with heavy blotching of infected leaves which get distorted with wavy margins and the leave lamina shows complete crinkling.

Potato Leaf roll virus

11. Potato stem necrosis virus (PSNV): The virus is transmitted by thrips. Necrosis of petiole, veins and stems at high temperatures. Stem losses turgidity and becomes brittle. Apical necrosis progress downward as browning and drying of foliage. Later on juvenile plants wither and wilt.

12. Marginal flavescence: It is a phytoplamasal disease and transmitted by leaf hopper. Marginal chlorosis of the top leaflets, puckering and slightly rough and thick stunted growth, profuse rooting few tubers at the base of the stem.

Rugose mosaic (X+Y)

13. Purple top roll: It is a phytoplamasal disease and transmitted by leaf hopper. Rolling of the basal part of the top leaflets accompanied by purple pigmentation, short internodes and swelling of nodes, numerous auxiliary branches.

14. Witch's broom: It is a phytoplamasal disease and transmitted by leaf hopper. Numerous thin stems with simple leaves giving an appearance of 'broom'.

15. Potato phyllody: It is a phytoplamasal disease and transmitted by leaf hopper. Petals become green giving a phyllody appearance.

Potato severe mosaic

Fungal and bacterial diseases

There are two types of diseases i.e. foliar and tuber-borne. In foliar diseases late blight, early blight, Phoma blight, Cercospora leaf spots and wilts are common. In tuber borne diseases brown rot, common scab, powdery scab, black scurf, late blight, charocal rot, pink rot, dry rot and wet rot are common.

1. Late blight *(Phytophthora infestans)*: The water soaked patches with whitish cottony growth along the lesion margins on the underside of leaflets in the early morning hours. Skin of tuber become brown, patchy and shrink. Discoloration of underneath tissue of tuber.

2. Early blight *(Alternaria solani)*: The brown to black, oval, large and circular spots with concentric rings.

3. Phoma blight *(Phoma exigua, P. sorghina)*: Small spots are brown to black, oval to irregular with variable size.

4. Leaf blotch (*Cercospora solani-tuberosi)*: Small chlorotic spots on the upper surface of leaves and a violet mildew on lower surface.

5. Fusarium wilt *(Fusarium oxysporum)*: Yellowing of margins of lower leaves followed by entire foliage, wilting of few stems followed by entire plant.

6. Bacterial wilt/brown rot *(Ralstonia solanacearum):* Dropping and rolling of leaves before wilting, succulent portion of plant becomes flaccid and droops. Wilting becomes permanent. A distinct brown discoloration in the vascular rings of cut tuber with slimy bacterial ooze.

7. Sclerotium wilt (*Sclerotium rolfsii*): Light yellowing, dropping and stunting of juvenile plants. Collar region of the stem infected with white mycelium which later on converted into brown mustard like sclerotia. The entire plants wilted and topple.

8. Charcoal rot *(Macrophomina phaseolina:* A high temperature disease at harvest. Tubers show black areas around the eyes and lenticels, flesh show black patches.

9. Wart *(Synchytrium endobioticum):* Prominent wart like outgrowth on the tubers which resemble cauliflower.

10. Common scab (*Streptomyces scabies*): Small radish or brownish spots on tuber surface, spots enlarge into circular or irregular lesions with sunken corky spot or pitted lesions having deep star shaped cracks or russetting of tuber surface.

11. Powdery scab (*Spongospora subterranea):*Small coloured blisters like pimples on tuber surface, pustules become dark and epidermis ruptures releasing brown powdery spore mass.

12. Black scurf (*Rhizoctonia solani*): Chocolate coloured, crusty scurf like irregular sclerotial mass on the surface of the tubers.

13. Dry rot (*Fusarium solani, F. equiseti*): Small sunken circular, oval or irregular brown lesions, flesh shows light brown discolouration and white cottony fungal growth.

14. Soft rot (*Erwinia carotovora*): Water socked lesions on tuber, tissue turns soft and pulpy/slimy, surface discolours with wrinkles and depressions.

15. Pink rot (*Phytophthora erythroseptica*): Blackening around lenticels and eyes, discolouration of flesh when cut and turns pink after exposure to air within few minutes and later on turns black.

Important insect-pests in seed crop

There are four types of insects which causes damage to the potato crop directly or indirectly. Directly, they damages leaf, stem and tuber while indirectly by sucking they transmit the viruses and phytoplasmas.

1. Aphids (*Myzus persicae* and *Aphis gossypii*): Wingless form is green, greenish, yellow or sometimes pinkish with a pair of well developed frontal tubercles. Winged form is with black head and green abdomen with dark patch on dorsal surface.
2. White-fly (*Bemisia tabaci*): Tiny, soft, white winged insect found mostly on the lower side of the leaves and suck the sap from succulent leaves.
3. Thrips (*Thrips palmi*): Sucking small, slender insect of <1 mm with fringed wings, adhered on the apical portion of the foliage. It will acquire tospo virus only at nymph stage but retain and transmit throughout their life.
4. Leaf hoppers: Sucking insects and vector for phytoplasmal disease like Purple Top Roll (PTR) and Marginal Flavescence (MF).
5. Cut worms (*Agrotis ipsilon, A. segetum*): The larval stage causes damage. They are dark grey or dark brown with faint spot/line on the body.
6. White grub (*Lachnosterna coriacea, Melolontha sp.)*: Fleshy, dingy white in color with brown head. Body is curved in an arch.
7. Tuber moth (*Phthorimaea operculella*): Larva is 15 to 20 mm with pinkish body and dark brown head. Adult moth has narrow silver grey body with grey body with grayish, brown wings having dark specks. It deposits eggs near the eyes on stored tubers.
8. Epilachna beetle (*Epilachna ocellata, E. vigintioctopunctata*): Hemispherical, body measuring 5 to 8 mm, posses 12 to 28 black spots on its elytra. The other species have 12 such spots encircled by lighter colour.
9. Golden/cyst nematode (*Globodera rostochiensis, G. pallida*): The cysts are of golden colour. Adult females are sessile globose or lemon shaped and males are motile and by depleting root cell contents an impair translocation system.

Integrated Pest and Disease Management

For production of good quality seed, various approaches are to be combined to control the diseases and pests. The good cultural practices are normally the basis of all efforts to control the diseases and pests. The general methods of control of potato diseases and pests are described below:-

Cultural practices

- Soil tillage brings the soil into better physical condition for plant growth and quick emergence, destruction of ground keeper and weeds which carry potato pathogens. It exposes the larvae and pupae of the insect for picking by the birds which help in reducing the insect population. Hot weather cultivation/summer ploughing of seed plot reduces the population of pathogens and desiccates the eggs of soil pests.
- Green manuring not only increases the potato yield but also helps in reducing the incidence of some soil-borne diseases like black scurf and common scab etc. It also helps in increasing the population of antagonistic micro-organisms.

- Roguing of diseased plants should be done as soon as the symptoms are visible in order to remove the source of infection and to prevent the spread of diseases. Haulms destruction is done to avoid spread of diseases caused by fungi (*Phytophthora, Alternaria* and *Phoma*) and viruses.
- Rotation must be adopted for 2 to 3 years with cereal crops to avoid build up of pathogens and parasites. Rotations should not include crops like pepper, brinjal, tomato, okra, cowpea and cucurbits which are hosts of common diseases of potato.
- The neighbouring fields may be the source of infection for late blight, viruses and infestation of aphids. Therefore, an isolation of five meter or more between seed and ware crop should be kept.

Chemical control

- Apply phorate 10 G @10 kg ha^{-1} at earthing up to control sucking pests and white grubs.
- Drench the ridges with chlorpyriphos 20 EC @2.5 liter ha^{-1} if damage of cutworm is observed.
- Spray the crop with 2.5 kg ha^{-1} mancozeb from third week of June onward at 10 days interval in the hills and 15th November onward in the plains as preventive measures. One spray of mixture of cymoxanil 8%+mancozeb 64% @2.5 kg ha^{-1} may be applied when late blight symptoms are observed. Subsequent sprays should be need-based.
- Spray oxydemeton-methyl 25% @1.25 liter ha^{-1} and imidacloprid @3 ml per 10 liter of water alternatively to control virus vectors (aphids and whitefly).
- Spray carbaryl @2.5 kg ha^{-1} to control defoliators i.e. epilachna beetle and semi-looper/caterpillars.

Potato Seed certification

As per the national policy of seed multiplication, the multiplication phases of seed have been grouped into three categories i.e. i) breeder or basic seed; ii) foundation-I and II and iii) certified seed. The breeder seed is considered to be pure, disease free and no tolerance limit is fixed while for foundation (FS-I and FS-II) and certified seed the tolerance limits for viruses off-type, tuber-borne diseases and grades have been fixed by Government of India. There shall be two types of seed potatoes, namely the hill and plain grown and shall be designated as hill seed and plain seed respectively. Hill seed shall be grown in the high hills generally 2500 m above the mean sea level or in situations declared technically suitable for seed production. Plain seed shall be grown in such areas where aphid infestation is low during crop growing season and which are technically suitable for seed production. A crop of seed potato shall not be eligible for certification if grown on land infested with wart *(Synchytrium endobioticum)*, common scab *(Streptomyces scabies),* brown rot or bacterial wilt *(Ralstonia solanacearum)* and or cyst forming nematodes (*Globodera pallida, G. rostochinensis*) or non-cyst forming nematodes within the previous three years.

A minimum of four inspections shall be made as follows:

- The first inspection shall be made about 45 days after planting in the hills and about 35 days of planting in the plains to verify the isolation, off-types and the extent of disease infection with specific reference to mild and severe mosaic, leaf roll, yellows, brown rot and other relevant factors.
- The second inspection shall be made about 60-65 days after planting for early varieties and about 70-

75 days after planting for late varieties or at appropriate growth stage depending on the crop duration of the variety concerned.

- The third inspection shall be made immediately after haulms cutting/destruction in order to verify that haulms have been cut/ destroyed by the prescribed date and in proper manner.
- The fourth inspection shall be made in about 10 days after haulms cutting/destruction and before harvesting in order to verify that no re-growth of haulms has taken place.
- Minimum four counts of 100 plants each are taken randomly on four spots in a zigzag manner in one hectare area. For each additional hectare or part there of two samples of 100 plants each are observed for all visible mosaics, other diseases and off-types.

Final field inspection for certification is carried out provided if the following two conditions are fulfilled i) The previous history of the field, crop operations followed, manuring and plant protection schedule should be made available at the time of inspection and ii) Final roguing should be done before certification inspection. At the time of roguing, all off-type and diseased plants should have been removed along with the tubers.

Field standards

Minimum isolation distance of five meter is to be given for foundation-I, foundation-II and certified seed crop from the fields of other varieties and also the fields of the same varieties not confirming to varietal purity requirements for certification. The minimum permissible limits for the certification of potato seed are given table.

Factors	Stage	Maximum permissible limits		
		Foundation -I	Foundation -II	Certified
Off-types	1st and 2nd inspection	0.05%	0.05%	0.10%
Mild mosaic	1st and 2nd inspection	1.0%	2.0%	3.0%
Severe mosaic, leaf roll and yellows	1st and 2nd inspection	0.5%	0.75%	1.0%
*Total virus	1st and 2nd inspection	1.0%	2.0%	3.0%
**Plants infected by brown rots	1st and 2nd inspection	None	None	3 plants per hectare
***Re-growth of plants after haulms cut/destruction	4th inspection	0.5%	0.5%	0.5%

* Of the two inspections, the higher virus percentage will be considered for the purpose of the specified limit of tolerance.

** The presence of brown rot infected plants within the specified limits of tolerance shall be permitted in the areas known to be infected with this disease. In case of plants suspected to be infected with brown rot, the neighbouring plants, one on the either side also are to be rogued along with tubers.

*** Standards for re-growth after destruction of haulms shall be met at 4th inspection to be conducted about 10 days after haulms cutting. Gaps in the seed plot should not be more than 10.0% and hualms must be destroyed as close to the ground as possible before the date specified by the certification agency. Failure to destroy haulms in time shall be render the crop liable for rejection.

Seed standards

Specifications in respect of size and weight of seed material for FS-I, FS-II and certified class are given in table.

Type of seed	Grade	Size (mm)	Corresponding weight (g)
Hill seed	Seed size	30 to 60	25 to 150
	Large	Above 60	Above 150
Plains seed	Seed size	30 to 55	25 to 125
	Large size	Above 55	Above 125

The size of tuber will be decided either on the basis of mean of two width of a tuber at the middle and that of length or on the basis of corresponding weight of tuber. In a seed lot, tuber not confirming to specific size of seed shall not exceed more than 5% (by number). The seed material shall be reasonably clean, healthy, firm and shall confirmed to the characteristics of the variety. The tubers not confirming to the varietal characteristics shall not exceed 0.05% and 0.1% (by number) for foundation and certified classes respectively. Cut, bruised, un-shape, cracked tubers or those damaged by insects, slugs or worms shall not exceed more than 1% (by weight). Greenish pigmentation on tubers will not be a disqualification for certification. Maximum tolerance limit of tuber showing visible symptoms of the diseases are given in table.

* Even if a single tuber infected with common scab is detected in a seed lot, the entire seed lot shall be treated with approved fungicide before seed lot is declared fit for certification. Seed lot having infected tuber more than prescribed limit will not be certified even after treatment.

** A tuber carrying 10% or above scurfed surface will be considered as one infected unit. However, seed lot having black scurf infection more than prescribed limits could be certified after treatment with approved chemical/fungicide.

Diseases	Maximum permissible limits (by number)		
	Foundation-I	Foundation-II	Certified
Late blight, dry rot or charcoal rot	1%	1%	1%
Wet rot	None	None	None
*Common scab	3%	3%	5%
**Black scurf	5%	5%	5%
***Total diseases	5%	5%	5%

*** For all diseases, the higher disease percentage will be considered for the purpose of the specified limits of tolerance.

Quality control

Quality control test is being done to determine the genetic purity of a given seed lot of released cultivars and the extent to which the given sample confirm to the prescribed standards. The samples for grow out test is to be drawn simultaneously by the seed supplier and the seed recipient by following the standard procedure. In a lot of 100 quintal, 250 seed potato tubers are drawn by each party along with tag having details of source of seed, variety and lot number. Grow out test is performed by growing the sample seed tubers in the next crop season as per standard package of practices. During this test, observation on germination, morphological characters and incidence of viruses are recorded to ascertain their genetic purity.

Certification standards for Potato-Tissue Culture-Raised Minituber (PTCMT)

As the name implies, the standards are applicable to tissue culture raised minitubers multiplied under laboratory and greenhouse conditions. The general standards are amplified as follows to apply specifically to the PTCMT. Laboratory and greenhouse facilities used for production of plantlets/microtubers or minitubers should be maintained free of potato pests or vectors of potato pathogens. All potting or growth media should be sterile and water to be used in a laboratory or greenhouse operation should be free from impurities. Hygienic conditions should be strictly observed during micropropagation, potting, planting, irrigating, movement and use of equipment and other laboratory and greenhouse practices to guard against the spread of diseases or pests in the facilities used for seed multiplication. All micropropagation and greenhouse facilities must be approved, as per the standard/guidelines. These facilities must have a changing area between the double doors. The greenhouse must be "insect-proof" and be equipped with a double-door entrance, provision for footwear disinfection prior to entering the protected environment and insect proof ventilation screening on intakes and exhaust openings. The persons entering the protected environment should use Wellington boots (Plastic boots) and change lab-coat in the changing area to reduce the chances of inadvertent introduction of vector insects clinging to clothes. The material being initiated for producing PTCMT must be of Registered/Notified variety and confirmed identity. It must be duly documented with respect to origin. The plants of a potato varieties being initiated for tissue culture should be tested in an accredited laboratory for freedom from PVA, PVS, PVM, PVY, PVX, PLRV, PALCV, PSTVd and endophytic or epiphytic bacteria and fungi. Tests must be carried on a minimum of ten plantlets of each variety selected at random. For virus testing, ELISA or an equivalent method should be used and viroid RT-PCR should be used while for fungi and bacteria light microscopy and culturing on media should be used. The facility should use recognized aseptic initiation and propagation procedures (i.e. follow procedures and use equipment, which will maintain sterile conditions as per standard tissue culture morns). The initiating facility must maintain information on variety identification, date of initiation, origin and testing results from accredited laboratory for review and audit by the competent authority once in a year. Valid pathogen testing results are required prior to the initiation of microtubers production cycle or planting of test tube plantlets in the greenhouse. PTCMT shall be produced and multiplied from approved source *in vitro* plants or microtubers, as per the prescribed procedure. PTCMT may be used for further pre-basic and breeder seed production. The soil used for PTCMT production should not be infested with pathogen and pests of potato, particularly of wart *(Synchytrium endobioticum)*; non-cyst forming or cyst forming nematodes; brown rot *(Ralstonia solanacearum)*; common scab *(Streptomyces scabies)* within the previous three years.

The grower must notify the Competent Authority of his production plans well in advance of the planting. The crop must be grown from approved basic source *in vitro* plants or microtubers, which were produced, in an aseptic environment. A minimum of three inspections shall be made. The first inspection should be made 35 days and 45 days after planting for plains and hills respectively to verify growing conditions, extent of disease infection and off types and also to confirm isolation requirement of one meter between different varieties as to avoid mechanical admixture. The second inspections should be made at 60-65 days after planting to verify off-types, disease infection if any and pathogen testing, on a representative sample, comprising of 1% of the plants with a minimum of 5 and a maximum of 25 plants sampled for each variety. The third inspection should be made immediately after haulms cutting/destruction in order to verify that haulms have been cut/ destroyed by the prescribed date and proper manner. Basic stock can be planted in commercially available medium, which has not been recycled. If nursery beds are used, the substrate should be properly sterilized before planting. The greenhouse must be free from all potato and solanaceous plant debris before planting. No field-produced seed potatoes (including pathogen tested clonal selections), non-seed potatoes, nor any other solanaceous species of plants can be grown in the protected environment while used to produce basic stock. Varieties must be separated by appropriate partitioning of greenhouse to prevent varietal mixture. If testing performed by an accredited laboratory reveals the presence of banned viruses, fungus or bacteria all the crops in the protected environment will be ineligible for multiplication and the entire material will be destroyed. In the eventuality of detection of insect- vectors particularly aphids, thrips and white flies, yellow sticky traps should be put at least at three places in a greenhouse. A representative sample of each variety grown in the protected environment must be post harvest tested and the results must provide to the authority and if the results are negative for PVA, PVS, PVM, PVY, PVX, PLRV and PALCV, the crop will be assigned basic stock status or otherwise rejected. The minimum permissible limits and seed standards for certification of PTCMT are given in table.

Factor	**Maximum permissible limits/standards**
* Off-types	0.05%
**Plants showing symptoms of Mild mosaic	0.05%
Servere mosaic, leaf roll, yellows and apical leaf curl	0.05%
**Plants infected by brown rot (syn. Bacterial wilt) (*Ralstonia solanacearum*)	Nil
Weight of minituber (minimum)	1.0 g
Germination/sprouting (minimum)	90%
Varietal Purity (minimum)	99%
Pure seed	98%
Virus	0.01%

*Maximum permitted before dehaulming

** Maximum permitted at final inspection, though the diseases mentioned above are not expected to be present in tissue culture raised plants but it essential to maintain good crop hygiene.

Key to the Aphids Infesting Potato, their Field Identity, Host Plants, Distribution and Virus Transmission

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Abstract

There are a number of viruses infecting potato crop throughout the world and most of them are spread through vectors. The most important ones are potato leaf roll virus and potato virus Y which are spread by different aphid species. Other viruses like PVA, PVM, and PVS, etc. are also spread by aphids. We provide key to the aphids infesting potatoes throughout the world and furnish information on their field identity, host plants, distribution and viruses transmitted by them. Field characters and key will help in quick identification of vectors and information on distribution may help to locate the areas that are likely to be free of their occurrence for healthy potato seed production.

Key Words: Aphids, potato, virus transmission

Economic importance of aphids

Aphids are phloem feeders and attack all parts of plants including roots. They directly damage the plant by sucking their nutrient resulting in curling and twisting of tender parts and general devitalisation. Some species cause stem and leaf galls. They also excrete copius honeydew, which hinders normal physiological processes of plants like photosynthesis and respiration. Deposition of honeydew on leaf surface also leads to the growth of sooty mould (*Capnodium* spp.). Polyphagism may reach as high as in *Aphis gossypii* Glover and *M. persicae* (Sulzer) that can develop on 400 and 270 species of plants, respectively in India (Raychaudhuri, 1980; Chakrabarti and Sarkar, 2001). Kennedy *et al.* (1962) listed 247 viral diseases, among which 164 were stated to be transmitted by nearly 200 species of aphids. Most of the non-persistent viruses like *Beet yellow stunt virus (BYV)* and persistent virus like *Potato leaf roll virus (PLRV)*, banana bunchy top, a DNA virus are also transmitted by aphids (Ghosh, 1980). Other important viruses transmitted by aphids are *Barley yellow dwarf virus* of cereals, *lettuce necrotic yellows viruses*, chilli mosaic and cucurbits and *banana bunchy top virus*. Ghosh (1974) provided a list of virus transmitted by aphids in India. *M. Persicae* alone transmits more than 100 plant viruses (Eastop, 1958).

Potato and plant viruses

Potato, a vegetatively propagated crop, needs large quantities of healthy/disease-free seed for its successful cultivation without losing productivity. There are a number of viruses infecting potato crop throughout the world and depending on the agro-climate many of them are spread through vectors. The most important ones are Potato leaf roll virus and Potato virus Y which are spread by different aphid species. Other viruses like PVA, PVM, QPVS, etc. are also spread by aphids.

In European countries, aphids appear on potato in the spring season, mostly migrating from the primary host plants that do not harbour potato viruses, hence they are not viruliferous. However, in the Indo-Gangetic plains, 80 per cent of potato crop is raised in autumn season and the main vector appears later in the growing period, migrating from the secondary host plants often harbouring the potato viruses. In India, potato crop is raised round the year in the plains, plateau or hills. Therefore, for achieving the best

results in potato cultivation, multiplying viruses free seed stocks in a suitable area/period free of vectors, is most important.

Forecasting of crop pests and virus-vectors is generally done by establishing relationships between pest population and weather parameters like temperature, rainfall, relative humidity, sunshine hours, cloudiness, dew duration, etc. The pattern of population build up of pests is a basic study for subsequent development of pest forecasting model. Timely and accurate forecasting helps in economic use of pesticides for getting the best results.

Species identification and its significance

Identification of insect pests has been a challenging task over centuries. The presence of different morphological forms (nymphs, wingless adults and winged adults) of a single aphid species on different hosts and at different times makes it difficult to identify routinely collected field samples. In addition to this many aphid species have different colour morphs which make them difficult to distinguish in live condition. Reliable identification of aphid species is essential for the effective management and for the early detection of vectors. Hence, diagnostic characters of some major aphid species are published in this folder to help researchers and students to identify commonly occurring aphid species.

In this document we have provided information about the species of aphids infesting potato, keys to identify them, viruses transmitted by each species and their distribution, host plants and biology.

Keys to aphid species

Fourteen species from potato are known to infest potato throughout the world. These species which have been included in the key are as given below.

Aphis fabae, A. frangulae, A. nasturtii, Pemphigus sp, A. spiraecola, Rhopalosiphoninus latysiphon, Aulacorthum circumflexum, A. solani, Rhopalosiphum rufiabdominalis, Macrosiphum euphorbiae, Smynthurodes betae, Myzus ascalonicus, M. ornatus and *M. persicae*

[Also recorded one or more times from potato but not included in the key are *Acyrtosiphon malvae, Geoica* sp. and *Uroleucon compositae*]

1. Terminal process much shorter than base of last antennal segment----------**2**
   —Terminal process much longer than base of last antennal segment----------**3**

2. Body and appendages with numerous hairs. Abdomen without wax pore-plates.----------
   ----------*Smynthurodes betae*

   ---- Body and appendages with very sparse inconspicuous hairs. Abdomen wax pore-plates on posterior segments----------*Pemphigus* sp.

3. Antennal tubercles weakly developed----------**4**

   ----Antennal tubercles well-developed----------**8**

4. Antennal hairs very long, the longest more than 3 times longer than basal diameter of antennal segment III---------- *Rhopalosiphum rufiabdominalis*
   ----Antennal hairs rarely more than 2 times longer than basal diameter of antennal segment III --------
   ----------**5**

5. Cauda pale, sometimes dusky in large specimens, but then clearly paler than siphunculi----------**6**
---- Cauda dark like siphunculi----------**7**

6. Siphunculi uniformly dark. Hairs on hind femur all shorter than diameter of femur at its base----------
----------*Aphis frangulae* group

---- Siphunculi usually rather pale, darker at apex. Hairs on hind femur mainly longer, some of them about as long as, or longer than, diameter of femur at its base----------*Aphis nasturtii*

7. Dorsal abdomen with small dark sclerites at least laterally on segments anterior to siphunculi, and transverse dark bands on tergites 7 and 8. Cauda without any clear constriction----------
---------- *Aphis fabae*
----Dorsal abdomen without any dark markings. Cauda usually with a constriction----------
----------*Aphis spiraecola*

8. Siphunculi jet-back with distal part very swollen---------- *Rhopalosiphoninus latysiphon*

---- Siphunculi pale or dusky, tapering, cylindrical or only slightly swollen----------**9**

9. Dorsal abdomen with a large black, roughly horseshoe-shaped patch, and thorax with paired black patches----------*Aulacorthum circumflexum*

---- Dorsal cuticle unpigmented or without extensive dark patches----------**10**

10. Dorsal abdomen with an intersegmental pattern of dark ornamentation. Terminal process less than 2.5 times longer than base of last antennal segment. Siphunculi tapering, with a shallow S-curve, and coarsely imbricated. Small oval aphid less than 2mm long----------
----------*Myzus ornatus*
---- Dorsal abdomen without any clear intersegmental markings. Terminal process more than 2.5times longer than base of last antennal segment. Siphunculi tapering, cylindrical or clavate, not coarsely imbricated. Small, medium rather large aphids----------**11**

11. Inner faces of antennal tubercles clearly divergent. Siphunculi long, with a subapacil zone of polygonal reticulation. Cauda long, 0.14-0.20 of body length.Rather large, spindle-shaped aphid-----
----------*Macrosiphum euphorbiae*

---- Inner faces of antennal tubercles convergent or parallel. Siphunculi without any polygonal reticulation. Cauda shorter, less than 0.125 of body length. Small to medium sized oval aphids--------
----------**12**

12. Siphunculi gradually tapering from base to flange, with no sign of a swelling on distal half. Antennal segment III with a single rhinarium near the base---------- *Aulacorthum solani*
---- Siphunculi slightly to moderately swollen on distal half. Antennal segment III without any rhinaria----------**13**

13. Siphunculi rather small, shorter than antennal segment III, with minimum diameter of basal half less than diameter of middle part of hind tibia. Inner faces of antennal tubercles approximately parallel in dorsal view----------*Myzus ascalonicus*

---- Siphunculi longer than antennal segment III, with minimum diameter of basal half greater than diameter of middle part of hind tibia. Inner faces of antennal tubercles convergent in dorsal view------ ----------*Myzus persicae*

In following paragraphs we have provided basic information on all the above mentioned aphid species.

Aphis fabae Scopoli {Black bean aphid}

Appearance in life: young colonies consist of matt black aphids on young shoots and older colonies Spread over most of aerial parts of plant with many individuals developing white wax marking. Regularly ant-attended. Apterae 1.5-3.1 mm, alatae 1.3-2.6 mm.

Host plants: very polyphagous on its secondary host plants, which include many crops. Particularly importants for its direct feeding damage to *Vicia fabe*, and as a virus vector in sugar beet.

Distribution: Widespread in temperate regions of the northern hemisphere, also in South America and Africa, but not common in the hotter parts of the tropics and the Middle East, where it tends to be replaced *by A.fabae solanella.*

Virus transmission: A vectore of more than 30 plant pathogenic viruses, including non- persistent Viruses of beans and peas, beets, crucifers, cucurbits, *Dahilia*, potato, tobacco, tomato and tulip and the persistent *luteo* viruses beet yellow net and potato leaf roll virus.

Aphis frangulae Kaltenbach

In central Europe, aphids closely related to, and virtually indistinguishable from, *A. gossypii* (*q.v.*) occur on potato and various other herbaceous plants (*Capsella*, *Lysimachia*, but not Cucurbitaceae). Unlike the anholocyclic A. *gossypii*, these other forms are holocyclic, with *frangula alnus* as primary host. The *A. frangulae* complex is discussed by Thomas (1968) who recognizes a number of subspecies, only some of which colonize potato, and by Stroyan (1984). The 'large cotton aphid' referred to by Khushbaktov (1995) under the name *A. frangulae* as a pest of cotton in Uzbekistan is probably *Acrythosiphon gossypii.*

Aphis nasturtii Kaltenbach {Buckthorn-potato aphid}

(= *A. abbreviate* Patch; = *A. rhamni* of many authors)

Appearance in life: Apterous adults bright yellowish green, with siphunculi pale or only slightly dusky; the body colour is rather constant, in contrast to the considerable colour variation in the closely related *A. gossypii-A. frangulae* group (*q.v.*) Apterae 1.3-2.0mm, alatae 1.2-2.0mm.

Host plants: Primary adults is buckthorn, *Rhamnus cathartica* and *R. alnifolia*. Polyphagous on secondary host plants in several families including Solanaceae (*Solanum nigrum*, potato), Cruciferae (*Nasturtium, Capsella*), and polygonaceae (*Beta vulgaris, Polygonum*).

Distribution: Throughout Europe, the Middle East, northern India Pakistan. Far East (Japan); introduced in North America, and recently recorded for the first time Chile (Eastop *et al.*, 1997). Also recorded from Ethiopia, Kenya and South Africa (Millar, 1990).

Virus transmission: An efficient vector of the non-pesistent Potato A *potyvirus*, potato Y *potyvirus*, and aucuba mosaic *potexvirus*, but a poor vector of potato leafroll *luteovirus*. Populations of *A. Nasturtii* do not usually seem to be a problem in seed potato production.

Aphis spiraecola Patch {Spiraea aphid; green citrus aphid}

(=*citricola* van der Goot of recent authors, including Blackman and Eastop, 1984)

Appearance in life: Small aphid, often curling and distorting leaves near stem apices of host plants, or on flower heads, and usually ant-attended. Body bright greenish yellow or yellowish green to apple green, with head brown. Legs and antennae mainly pale but siphunculi and cauda dark brown to black. Alatae have head and thorax dark brown, abdomen yellowish green with a dusky lateral patch on each segment, Apterae 1.2-2.2mm.

Host plants: A very polyphagous aphid with numerous host plants in over 20 families, but especially on Caprifoliaceae, Compositae, Rosaceae, Rubiaceae and Rutaceae, and particularly on plants of shrubby habit. *Citrus* is probably its most important crop host.

Distribution: Probably of Far Eastern origin. It has been in North America at least since 1907, and was introduced more recently to the Mediterranean region (about 1939), Africa (1961), Australia (1926) and New Zealand (1931).

Virus transmission: A vector of citrus tristeza *closterovirus*, cucumber mosaic *cucumovirus*, papaya ringspot *potyvirus*, plum pox *potyvirus*, potato Y *potyvirus*, viburnum strain of alfalfa mosaic *alfamovirus*, water melon mosaic 2 *potyvirus* and zucchini yellow mosaic *potyvirus*.

Aulacorthum* (Neomyzus) *circumflexum (Buckton) {Mottled arum aphid}

Appearance in life: Apterous adults shiny, nearly white or plae yellow to bright green, with distinctive sclerotic dorsal markings, consisting of transverse bands or paired patches on the thorax and a large, usually roughly horseshoe-shaped, patch on the abdomen. Antennae, legs, siphunculi and cauda mainly plae. Alatae occur rarely. Apterae 1.2-2.6mm, alatae 1.6-2.4mm.

Host palnts: Exteremely polyphagous, feeding on numerous species of both monocots and dicots. It has even been found feeding on ferns and conifers. In temperate climates this aphid occurs particularly in glasshouses, and it is a common pest of house plants (e.g. *Cineraria*, Cyclamen, *Fuschia*, *Zantedeschia*).

Distribution: Virtually world-wide, presumably due to transportation by man. Origin unknown, but East Asia seems most likely. IIE Distribution Map No. 172 (revised 1990).

Virus transmission: Shown to be able to transmit over 30 plant viruses, including the persistent viruses barley yellow dwarf *luteovirus*, pea enation mosaic *enaomvirus* and potato leafroll *luteovirus*, and non-presistent viruses of beans, beet, cauliflower, celery, *Dhalia*, onion, potato, radish, soybean, tobacco and tulip. However, in colder climates *A. circumflexum* is not important as a vector because it rarely occurs outdoors.

Aulacorthum solani (Kaltenbach) {Glasshouse-potato aphid; Foxglove aphid}

Appearance in life: Colour of apterae variable; from a rather shiny, whitish green or yellow, in which case there is usually a conspicuous bright green or rust-coloured spot at the base of each siphunculus, to a uniformly dull green or greenish brown. Appendages mainly pale except for dark brown apices to the tibiae, siphunculi and antennal segments. Alatae look quite different, with dark brown head and thorax, much darker antennae, legs and siphunculi, and a variably developed pattern of transverse dark bars on the dorsal abdomen. Apterae and latae 1.8- 3.0mm.

Host plants: Extremely polyphagous, colonizing plants in many different families of both dicots and monocots (but not Gramineae). Bulbs (especially tulips) often have large populations of *A. solani*, and it is a common pest in glasshouses and on pot plants.Common on potatoes and on soyabean in Korea and Japan.

Distribution: Probably of European origin, but now almost world-wide.

Virus transmission: A vector of about 40 plant viruses including both persistent and non- persistent viruses of beet and potato. Muller *et al.* (1973) studied intraspecific variation in the ability to transmit pea enation mosaic *enamovirus*. Okubo and Hashimoto (1992) studied spread of soybean dwarf *luteovirus* by alate *A. solani* in Japan.

Macrosiphum euphorbiae (Thomas) {Potato aphid}

(=*solanifoli* Ashmead)

Appearance in life: Adult apterae medium-sized to rather large, spindle-shaped or pear-shaped, usually some shade of green but sometimes yellowish, pink or magenta, often rather shiny. Eyes are distinctly reddish. Legs, siphunculi and cauda mainly same colour as body, but siphunculi often darker towards spices; antennae usually only dark apically, but sometimes almost entirely dark. Immatures rather long-bodied, paler than adults with a dark spinal stripe and a light dusting of whitish-grey wax. Alatae have pale greenish to yellow-brown thoracic lobes, and usually only the antennae and siphunculi noticeably darker than in the aptera. Apterae 1.7-3.6mm, alatae 1.7-3.4mm.

Host palnts: Primary host *Rosa* spp.; highly polyphagous on secondary hosts, feeding on over 200 plant species in more than 20 different families. Solanaceae, especially *Solanum tuberosum*, are particularly favoured secondary hosts.

Distribution: Apparently of North American origin, now almost world-wide. (The spread into eastern Asia took place only rather recently.)

Virus transmission: A vector of over 40 non-persistent viruses and five persistent viruses including beet yellow net, pea enation mosaic, bean leaf roll, sweet potato leaf-speckling virus (Fuentes *et al.*, 1996), zucchini yellow mosaic, and Potato leaf roll. However, it appears to be unimportant as a vector of potato leaf roll under field conditions in comparison with *Myzus persicae* (Robert, 1971; woodford *et al.*, 1995).

Myzus ascalonicus Doncaster {Shallot Aphid}

Appearance in life: Apterae are shiny pale-greenish brown, straw-coloured or dirty yellow, with dorsum strongly convex in comparison with related species and the inner faces of the antennal tubercles are almost parallel, rather than convergent as in typical *Myzus*. Appendages are mainly pale except that the apex of antennal segment V, the whole of VI, the apices of the tibiae and the tarsi, are all quite black. Alatae have a black dorsal abdominal patch, dark siphunculi and cauda and a remarkably bimodal variation in the number of secondary sensoria on the antenna, either a few near the base of segment III or large numbers covering III, IV and V. Apterae 1.1-2.2mm, alatae 1.3-2.4mm.

Host plants: Extremely polyphagous, colonizing plants in over 20 families, particularly Alliaceae (*Allium ascalonicum*, *A. cepa*); Caryophyllaceae (*Cerastium*, *Stellaria*); Compositae (e.g. *Lactuca*, *Chrysanthemum*, *Taraxacum*, *Crepis*); Cruciferae (*Brassica*, etc.); Liliaceae (*Tulipa*); and Rosaceae (*Fragaria*, *Dasiphora*).

Distribution: Europe, India, Pakistan, Japan, Australia, New Zealand, Antipodes, Auckland Isles and North and South America. The origin of *M. ascalonicus* is a mystery; it was first collected on stored onion sets in Wyoming, USA, in 1940 (Fronk, 1955) and a year later on stored shallots in Lincolnshire, UK.

Virus transmission: A proven vector of about 20 plant viruses including beet mosaic, beet western yellows, cauliflower mosaic, cucumber mosaic, dandelion yellow mosaic, onion yellow dwarf, potato leaf roll, shallot latent, strawberry mottle, strawberry veinbanding, tomato dwarfing, turnip crinkle and turnip mosaic (as cabbage black ringspot). Not a vector of lettuce mosaic, potato virus Y, or the persistent strawberry viruses. Important particularly for its ability to transmit viruses from wild, overwintering hosts to crops, e.g. beet mosaic *potyvirus* from *Stellaria media* (Semal, 1956) and dandelion yellow mosaic *sesquivirus* from *Taraxacum* to lettuce (Kassanis, 1947).

Myzus ornatus Laing {Violet aphid}

Appearance in life: Apterae are small or very small, oval, somewhat dorsoventrally flattened, pale-yellow or green, marked dorsally with a characteristic pattern of dark-green or brownish dots and transverse streaks; they live singly on the leaves of the host plants. Alatae have black central dorsal patch on the abdomen, dark antennae and dusky siphunculi and cauda. Apterae 1.0-1.7mm, alatae 1.2-2.1mm.

Host plants: Very polyphagous; on many different plant families including especially Bignonaceae, Compositae, Labiatae, Polygonaceae, Primulaceae, Rosaceae and Violaceae.

Distribution: Distributed throughout the world, probably on ornamental plants. Although common in India since 1956, there is still only one record from South-East Asia (New Guinea).

Virus transmission: Able to transmit at least 20 plant viruses, including the persistent viruses *beet western yellows, pea enation mosaic, Potato leaf roll* and *strawberry crinkle* and non- persistent viruses of crucifers, cucurbits, *Dahlia*, onion, potato, *Primula*, soybean, strawberry and tomato.

Myzus persicae (Sulzer) {Peach potato aphid; Green peach aphid}

Appearance in life: Adult apterae small to medium-sized, whitish green, pale-yellow-green, grey-green, mid-green, pink, red or almost black (apart fro genetically determined colour variation, any one genotype will be more deeply pigmented green or magenta in cold conditions); rather uniformly coloured, not shiny. Alatae have a black central dorsal patch on the abdomen; immature of the alate morph, especially in autumn populations, are often pink or red. In colonies curling young leaves of peach in spring, or in usually more dispersed populations on many other plants, often on older leaves. Apterae and alatae 1.2-2.1mm.

Host plants: Primary host usually *Prunus persica* including var. *nectarina*, sometimes *P. nigra*, *P. tenella* and possibly *P. serotina* and peach-almond hybrids. Secondary hosts are in over 40 different plant families and include very many economically important plants. Populations colonizing tobacco have been distinguished as a sibling species, *M. nicotianae* (Blackman, 1987), but recent studies indicate that some hybridization between the tobacco form and *M. persicae* s. str. occurs in regions where both forms migrate to peach.

Distribution: Probably of Asian origin, like its principal primary host; now world-wide.

Virus transmission: The most important aphid virus sector, shown to be able to transmit well over 100 plant viruses (Kennedy *et al.*, 1962). Persistent viruses transmitted include bean leaf roll, beet western

yellows, beet mild yellowing, beet yellow net, pea enation mosaic, potato leaf roll, tobacco vein-distorting, tobacco yellow net and tobacco yellow vein. The relationship with *Potato leaf roll virus or Potato leaf roll luteo virus* has received particular attention (e.g. Ponsen, 1972; Eskanderi *et al.*, 1979). Also a very efficient vector numerous non-persistent viruses; e.g. cucumber mosaic and bean yellow mosaic to lupins in Western Australia (Bwye *et al.*, 1997).

Pemphigus species on potato

The only record of a *Pemphigus* species on potato is by Strickland (1953), and is a species identified as *P. brevicornis* (Hart), which is possibly a synonym of *P. populicaulis* Fitch.

Rhopalosiphoninus latysiphon (Davidson) {Bulb-and-potato aphid}

Appearance in life: Apterae are shiny dark olive-green with very striking swollen shiny black siphunculi, living clustered on subterranean parts of growing plants or on bulbs or tubers in store. Immature stages are paler green with black siphunculi. Alatae have shiny olive-green to black dorsal abdominal markings. Apterae and alatae 1.4-2.5mm.

Host plants: On bulbs (*Tulipa*, *Gladiolus*) and potato tubers in store and on roots of many plants, especially in clay soils (e.g. potato crops), or on etiolated stems or runners growing in darkness under stones (e.g. *Bromus sterilis*, *Convolvulus arvensis*, *Potentilla anserine*, *Vinca major*, *Urtica* spp.). Ciampolini *et al.* (1993) recorded on outbreak on courgettes under glass in Italy.

Distribution: Europe, Egypt, Rwanada, Kenya, South Africa, India, Pakistan, Nepal, Sri Lanka, Japan, Australia, New Zealand and North and South America.

Virus transmission: Recorded as a vector of cucumber mosaic *cucumovirus* and beet yellows closterovirus and potato Y *potyvirus* (Bell, 1988). It also has the ability to transmit potato leaf roll *luteovirus* occasionally.

Rhopalosiphum rufiabdominalis (Sasaki) {Rice root aphid}

Appearance in life: Apterae on roots of secondary host plants are dark-green or olive with usually a reddish area at the posterior and of the abdomen between and around the siphunculi. The abdomen of the alata is similarly coloured. Apterae and alatae 1.2-2.2mm.

Distribution: Virtually world-wide, but of economic importance chiefly in warmer climates.

Host plants: Primary hosts are *prunus* spp. (*yedoensis*, *mume*, *donarium* varieties, *persica*, etc.). Secondary hosts are numerous species of Gramineae, Cyperaceae and some dicots, particularly Solanaceae (potato, tomato). Populations have been found on courgettes under glass in Italy (Ciampolini *et al.*, 1993). It is especially damaging to *Oryza sativa*; incidence of *R. rufiabdominalis* on different rice cultivars in India was studied by Dani and Majumdar (1978).

Virus transmission: A vector of barley yellow dwarf *luteovirus* (Paliwal, 1980).

Smynthurodes betae Westwood {Bean root aphid}

(= *Trifidaphis phaseoli* Passerini)

Appearance in life: Apterae on roots are small to medium-sized, almost globular, dirty yellowish white, wax-dusted, with light-brown head, prothorax, antennae and legs, the whole insect is clothed with

numerous fine hairs. Alatae have dark transverse bars on the abdominal tergites. Apterae 1.6-2.7mm, alatae 1.9-2.9mm.

Distribution: Virtually world-wide on secondary host plants.

Host plants: Primary hosts are *Pistacia atlantica* and *P. mutica*. Secondary hosts are numerous dicotyledons, particularly Compositae (*Artemisia*, *Arectium*), Leguminosae (*Phaseolus*, *Vicia*, *Trifolium*) and Solanaceae (*Solanum tuberosum*, *S. nigrum*, *Lycopersicon esculentum*); also some times on *Beta*, *Brassica*, *Capsella*, *Gossypium*, *Heliotropum*, *Rumex*, etc. Rarely on monocotyledons (Gramineae, Cyperaceae).

All the above mentioned aphids are not of regular occurrence on potato. Following species of aphids are found commonly infesting potatoes or other host plants. Potato viruses transmitted by them are given below in tabular form.

Aphid species	Virus Transmitted
Myzus ascalonicus	*Potato leaf roll*
Myzus ornatus	*Potato leaf roll*
Myzus persicae	*Potato leaf roll and potyvirus*
Macrosiphum euphorbiae	*Potato leaf roll and potato leaf speckling virus*
Aulacorthum solani	*Persistent and non-persistent viruses of potato*
Aulacorthum circumflexum	*Potato leaf roll and non-persistent potato viruses*
Rhopalosiphoninus latysiphon	*Potyvirus*

There are few aphid species which do not colonise on potato crop but can spread PVY. The list of these aphid species is furnished below.

Pea aphid, *Acyrthosiphon pisum*: Vector of potato virus Y. Transient in potato. Hosts: limited to members of Family Fabaceae (legume family), vetch species, and crimson clover in both summer and winter.

Cowpea aphid, *Aphis craccivora*: PVY vector. Transient in potato. Hosts: polyphagous, feeds on many species of Family Fabaceae (legume family).

Soybean aphid, *Aphis glycines*: PVY vector. Transient through potato. Host alternation: overwinters on buckthorn; soybeans summer host with feeding observed on other members of Family Fabaceae (legume family).

Thistle aphid, *Capitophorus elaeagni*: PVY vector. Transient through potato. Host alternation: overwinters as eggs on *Elaeagnus* spp., secondary hosts mainly thistles (*Cirsium* spp., *Carduus* spp.,*Cynara* spp., Family Compositae), found primarily on plants of Family Polygonaceae (knotweed family).

Corn leaf aphid, *Rhopalosiphum maidis*: PVY vector. Transient through potato. Hosts are primarily members of the Poaceae family (grasses), preferring sorghum as a host but also corn, barley, millet, sudan grass, and other cereals.

Bird cherry-oat aphid, *Rhopalosiphum padi*: PVY vector. Transient through potato. Host alternation: overwinters on woody perennials, bird cherry (*Padus racemosa*) or plum (*Prunus* spp.), summer hosts

are mainly in the Family Poaceae (grasses), especially maize, barley, oats, millet, and wheat. Heavy colonization on winter wheat in early spring and late fall.

Greenbug, *Schizaphis graminum:* Vector of potato virus Y. Transient through potato. Hosts include: sorghum, wheat, barley, corn, millet, oats, rice, and rye. Lawns may also be affected by greenbug infestations in the Midwestern U.S. Eggs laid into leaf sheaths of winter cereals or other grasses (Family: Poaceae). Nine current biotypes that differ in host preference.

English grain aphid, *Sitobion avenae:* PVY vector. Transient through potato. Host alternation: overwinters on winter cereals and grass weeds. In summer, it occurs primarily on cereals including maize, wheat, and rice. Can develop on many cultivated or wild species of the Family Poaceae (grasses) and some species of the Families Juncaceae (rush family) and Cyperaceae (sedge family).

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Status of Potato Seed System in Asia

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Introduction

In sub-tropical lowlands, potato is mainly cultivated as a sand-witch crop in cereal based cropping systems in winter and is the third most important crop after rice and wheat. In mid hills and highlands the potato is cultivated in spring and summer seasons. The major potato producing countries of Asia are documented in Table-1 (Anonymous 2013). In most developing countries of Asia, the majority of smallholder farmers use farm-saved seed potato obtained from non-specialized seed growers, owing to the lack of commercial seed production systems or, where they exist, to the high price of certified seed. Farmer-based informal seeds are generally unable to maintain seed quality by eliminating diseases such as viruses. Poor functioning of seed systems are consistently ranked by CIP as being among the major constraints to increase potato production. Simple, low-cost technologies are therefore,required to help many countries to produce and distribute the healthy seedneeded for sustainable and profitable potato production. The yield gap between the potential farm yield of potato and the actual average farm yield ranges up to 60% in some countries of Asia due to non-availability of quality seed of farmers' choice locally adapted varieties.A poor linkage between public and private sectors is lacking for developing region-specific potato varieties. Availability of new *varieties* with more prospect of added value for farmers can accelerate narrow down yield gaps. The poor quarantine systems of some countries have allowed introduction of serious seed borne pests and diseases with seed. Establishing regional hubs for breeding and seed production can facilitate farmers to get seed of locally bred varieties at adequate prices and check the introduction of new diseases through imported seed.The development of sustainable seed systems of locally developed varieties is important to benefit farmers to generate more income by reduced cost of seed. In this paper, the potato seed system of major potato producing countries of Asia has been discussed.

Afghanistan

Potato is one of the important crops of Afghanistan. The agro-climatic conditions of Afghanistan are ideally suitable for good quality potato seed production. Potato is cultivated in 21,500 ha with an average yield of 11t/ ha. Potato is grown during spring in mountains and during fall in the plains in irrigated lands. KufriChandramukhi and KufriLauvkar are popular varieties in Afghanistan. There is no formal seed system existing in the country. The potato produced in the hills during spring is used as seed for both spring and fall planting. More than 4000 farmers in Bahak district of and Badakhshan province district have started producing seed potato cultivation as source of their livelihood (Srinivas et.al 2012). Seed is stored in country stores built underground and aboveground

Bangladesh

The area under potato crop has increased significantly in last five years. Bangladesh produced 9.7 million

tons of potatoes from 0.53 million ha area in 2012. Total annual seed potato requirement of country is about 0.75 million tons. The supply of quality seed in the country is about 6 %, out of which Bangladesh Agricultural Development Corporation (BADC) produced seed is 1%, private sector's produced seed is 2% and private sector imported seed is 3% (Rabbani et.al 2010). In addition to public sectors, a NGO-BRAC has significant contribution in producing and supplying truthful seed to farmers. BRAC alone produced nearly 9000 tones seed in 2010. Nearly 7000 tones seed is imported annually from Netherland.

China

China is the second largest potato producer in the world. According to FAO, some12% of the world potato production is Chinese. Potato yields in China are low relativeto world level. Chinese potato yields average 16 t/ha, but regional average yields varies fromless than 5t/ha to as high as 30 t/ha. To expand virus-free seed potato coverage, theGovernment of China has included seed potato production into its subsidy program. According to thenew policy, basic seed potato (G2 seed) production will be subsidized at a rateof $1,100/ha (RMB500/mu). Industry experts indicated that the current subsidy policywould not work as well as expected because: 1) the subsidy is relatively low and 2) the subsidygoes to seed producers, not farmers. It is estimated that only 20 percent of the totalcultivable area is planted with quality seed

India

Potato in India is cultivated in different agro-ecologies and seasons. About 85% potato area is in the subtropical lowlands in winter under short day conditions. Nearly 7% potato area lies in the plateau region in the Peninsular India and remaining is in the mountains. In 2012, 45 million tones potatoes were produced from 1.9 million ha having productivity 23.68 t/ha.The Central Potato Research Institute (CPRI) has the mandate for potato research and development in India. The CPRI supplies nearly 2500 tone basic (breeder) annually to different organization for further multiplication into foundation and certified seed for distributing to the farmers. Beside public sector, private seed companies such as ITC are also involved actively in potato seed production. The formal seed meets about 25% seed requirement of the country and remaining 75% seed requirement is met by the informal seed produced in cooler region in North-West India.

Nepal

The potato is a staple food in mountains and plays an important role in the country's food security and poverty alleviation and occupies the fifth position in area. Despite its vital role in human diet and its high yield potentiality, the crop gives very poor yield; with average of 13.6 t/ha, which is far below to the neighboring countries. The National Potato Research Program is distributing about 100,000 minitubers with the increased awareness of potato farmers towards the use of clean seed. However, the seed demand throughout the country is almost 6,00,000 minituber every year. The country does not have any seed certification program. There is no formal import of the seed but since the border to India is open in three directions, informal way of seed entering in the country is not recorded.

Pakistan

Potato in Pakistan is grown in sub-tropical lowlands during autumn season in irrigated lands and in hills during spring season under rainfed conditions. Nearly 76% potatoes are produced in plains during

autumn. In 2012, 4.4 million tones potato was produced in 0.19 million ha with an average yield of 22.2t/ha. A large number of varieties are grown in Pakistan. The Desiree, Sante, Asterix, Diamant, Cardinal, Barna and Kuroda are the main varieties grown. The country produces nearly 1500 MT seed through formal system. In addition local seed, between 5000- 7000 MT is also imported annually of different varieties. The formal seed including imported meet hardly meets 2% seed requirement of farmers and remaining demand is met by informal seed.

Vietnam

Potato as a winter crop and is the secondmost important food crop after maize in the Red River Delta (RRD).Vietnam does not yet have a viable system of seed potato production and supply.Consequently, the lack of good quality seed has been considered the most importantconstraint to improving both the productivity of potato crops and the area of potatocrops cultivated.There are no registered seed potato producers in Vietnam and, as yet, there is no formalseed certification system. Seed multipliers are farmer-volunteers. Several researchinstitutions such as the Food Crops Research Institute (FCRI) and Vietnam AgriculturalScience Institute (VASI),multiply and supply a small amount of good quality seed tothe farmers, but the quantity is negligible. In general, most farmers retain and shareamong themselves, the small sized tubers harvested from the ware crop which arelocally regarded as seed tubers.

Indonesia

Like in other developing countries, the major constraint in potato production in Indonesia isthe lack of good quality and cheap seeds. Government agencies, non-governmentorganizations, and the private sector have attempted to produce seed potatoes in the last tenyears. Involvement of the private sector in local seed production activities increased in the lastseven years mainly due to the decline in seed imports to the country. The private sectorinvested very heavily in potato seed production by building net houses and tissue culturelaboratories in potato producing areas of Indonesia.Neither the private and nor the public sector however were able to produce seeds withadequate quality. Many of the private companies were unable to cope with the productioncosts and have terminated activities while a few are still struggling to survive. Some companies opted to import seed potatoes from developed countries andmultiply these locally to reduce costs and increase profits.

Seed System in Central Asia (CA)

In CA, Tajikistan and Turkmenistan reporting the highest and lowest productivity of 23.7 and 6.2 t/ha, respectively (Table 1). The CA countries do not have an efficient potato seed production system to provide clean seed at an affordable price to potato farmers. In countries like Kazakhstan and Uzbekistan, state enterprises import seed potatoes from Europe and multiply them for one or two generations. The price of formal seed is high because cost of transport of Elite seed categories from Europe. In order to radically improve the situation in the potato seed production sector, there are two options. The first is to develop a sustainable seed potato certification system for long day adapted, abiotic and biotic resistant varieties to reduce dependence on external sources of seed. Alternatively, it would be matter of improving the existing informal seed potato production system. To overcome the unavailability of good quality seed and the high cost of imported seed, CIP introduced TPS as an alternative seed production technology in Kyrgyzstan, Tajikistan and Uzbekistan. A lot of efforts were made by CIP and partners in each country.

Table 1. Area, Production and productivity of major potato growing countries of Asia

Country	Area (Ha)	Production (MT)	Productivity (T/Ha)
Afghanistan	21,500	235,000	10.93
Bangladesh	53,4000	9,740,000	18.24
India	1,900,000	45,000,000	23.68
Nepal	190,250	2,584,301	13.58
Pakistan	185,100	4,104,400	22.17
Indonesia	64,518	1,068,800	16.57
Vietnam	40,000	440,000	11.00
China	5,431,700	85,920,000	15.82
Kazakhstan	190, 200	3, 126,400	16.40
Kyrgyzstan	81, 517	1,312,699	16.10
Tajikistan	41, 700	990,200	23.70
Turkmenistan	45, 000	280,000	06.20
Uzbekistan	74, 000	1,900,000	25.70

SOURCE: FAOSTAT | © FAO Statistics Division 2013

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Anonymous: FAO Statistics Division 2013.

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Problems and Prospects of Seed Potato Production System in Non-traditional Areas with special reference to Karnataka

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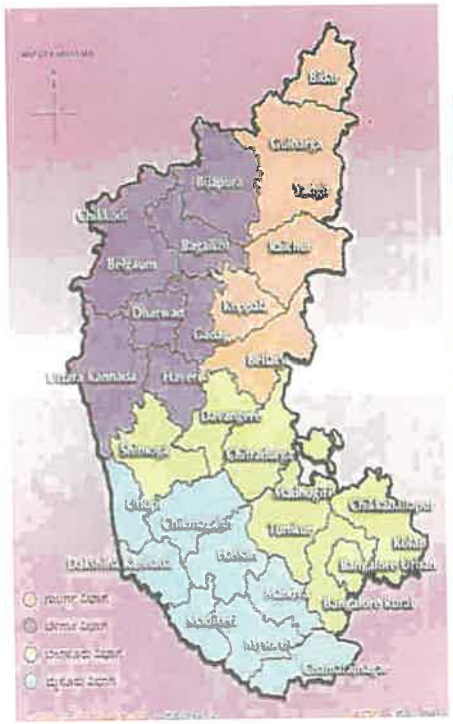
Potato is one of the four major food crops of the world, the others being rice, wheat and corn. It has been recognized as a nutritional gold mine and potato has come to occupy the centre stage in the fight against hunger. India ranks fourth among the potato producing countries and can rightly be proud of its record of average yield of 18.07 tonnes per hectare, which is higher than the world average of 17.0 tonnes. Some parts of plateau region of India are found to be ideal to cultivate potato. Plateau region comprises of coastal and peninsular India covering Maharastra, Karnataka and parts of Gujarat, Madhya Pradesh and Orissa.

The area under potato in Karnataka in previous decade was about 0.78 lakhs ha with a total production of 7.88 lakhs tonnes and productivity of 10.11tonnes/ha. However the area under potato is gradually decreasing due to non availability of quality seeds in local area and heavy crop loss due to late blight, dependency on north India for seed potato and free seed and input supply programme of Soyabean launched by government of Karnataka. As a result, some of the potato growing farmers are shifting from potato to Soybean. Even though the area under potato is decreasing, the productivity trend is found increasing due to recommendation and adoption new varieties like K. Pukhraj, K. Jawahar, K. Surya and K. Gourav in the state and innovative crop production technologies recommended by the Potato Scientists in Karnataka.



Crop at bloom stage (45 days).

Potato is being grown in four out of ten agro climatic zones of Karnataka *viz.*, Northern transitional zone (Belgaum and Dharwad), Southern transitional zone (Hassan), Eastern dry zone (Bangalore and Kolar) and hilly zone (Chickamagalur). Out of these six districts, Hassan district contribute around 35 to 40 percent of area and production in Karnataka. Potato is mainly grown as rainfed crop on black clay loam soils during *kharif* season in Dharwad and Belgaum district, which is an unique feature. However, it is being grown on red sandy loam in other parts of the state. Potato is one of the important cash crop of Karnataka hence there is a tremendous scope to increase the area and production by recommending potato as a inter crop with sugar cane, red gram and also with cotton and cultivation in non-traditional areas and seasons (*rabi* in traditional pockets).

The area and production of potato in Karnataka has been steadily increasing. During year 1970 the area under production was just 8800 ha but it has reached to 52000 ha during 2009-10. Similarly, the annual production and productivity has also increased (Table-1).

Table 1. Area, Production and Yield of Potato (2000 to 2012)

Year	Karnataka			Remarks
	Area (thousand ha.)	Production (thousand tonns)	Productivity (t/ha)	
1998-99	72.00	57.67	8.01	➢ Area under potato decreased due to inadequate seed supply, late blight incidence in southern Karnataka and launching of free seed supply (Soya bean and ground nut) programme of Government of Karnataka. ➢ Productivity has been found in increasing trend due to adoption new varieties and technologies recommended by the Potato Scientists.
1999-00	65.00	67.21	10.34	
2000-01	58.00	72.79	12.55	
2001-02	68.00	78.61	11.56	
2002-03	48.00	55.48	11.50	
2003-04	39.00	47.15	12.09	
2004-05	36.00	39.60	11.00	
2006-07	50.00	56.25	11.25	
2008-09	53.00	64.82	12.23	
2009-10	56.00	69.88	12.48	
2010-11	41.00	50.14	12.23	
2011-12	37.00	49.21	13.30	
2012-13	39.24	54.15	13.80	

The AICRP on Potato Centre is situated in the heart of the *Kharif* potato growing area of Karnataka. The average annual rainfall of the location is about 800 mm, which is fairly well distributed from May-June to Oct-Nov. The maximum and minimum temperature usually ranges from 25.00^0 C to 38.00^0 C and 12^0 C to 24^0 C during crop growth period. The potato soils of the region are deep black clay loams (Vertisols) with high moisture retentive capacity and are very fertile.

The All India Co-ordinated Potato Improvement Project (AICPIP), was also established in 1993 by ICAR at Dharwad, under University of Agricultural Sciences, Dharwad which was later shifted for UHS Bagalkot and is rendering service to the promotion of potato research and improvement work in northern parts of Karnataka.

This crop is grown mainly as rainfed crop during June to October in black cotton soils in Dharwad region and red loamy soils in Hassan and Kolar regions. The cultivars Kufri Chandramukhi and Kufri Jyothi are the only popular varieties being cultivated since long. But they have become susceptible to diseases and pests and have high fluctuation in yield. Further the potato farmers of Karnataka are experiencing great difficulties in obtaining the quality seed of the desired genotype. Recently released varieties like K. Pukhraj , K. Surya and K. Gourav are the new hopes for the farmers of Karnataka and in addition to this, alternate technology "True Potato Seed" is being tried.

The area under potato crop is gradually decreasing mainly due to marketing problems and uneven distribution of rainfall (in Dharwad and Belgaum only) Crop diversion due to free distribution of seeds and subsidies announced by Govt of Karnataka for soyabean to some of agricultural crops.

Table 2. Potato seasons - Period, diseases/pests, in Karnataka

Sl. No	Growing period	Pests	Diseases
1a. 1b.	*Kharif*(May– September) (Hassan) Belgaum and Dharwad (JuneOct)	Mites, PTM, Spodoptera , Helicoverpa.	Bacterial wilt Early blight Late blight, Sclerotium wilt, Viral and StemNecrosis
2a. 2b.	*Rabi* (October– March) (Hassan & Kolar) *Rabi* (Oct-Feb) (Belgaum and Dharwad)	Mites, PTM, Spodoptera, Helicoverpa.	Early blight, Late blight

The major varieties grown in Hassan, Kolar, Belgaum, Bangalore and Chikmagalore are Kufri Jyothi and K.Gaurav (JX-576) where as in Dharwad, Kufri Jawahar (JH-222), K. Pukhraj, and K.Surya are popular. Further the area under Kufri Gaurav is gradually increasing. The details of varieties cultivated in each districts is given in Table-3.

Table 3. District-wise Potato area under potato in the Karnataka State during 2012

Sl. No.	District	Area under potato (ha)	Potato varieties with approx. % area covered
1.	Hassan	25,791	K. Jyothi (98%) Atlantic & FTL-1533
2.	Kolar	3,653	K. Jyothi (90%) K. Chadramukhi (5), KCH-1&2)
3.	Belgaum	4,399	K. Jyothi (92%) others (8%)
4.	Bangalore (Rural)	735	K. Jyothi (70-80), K. Gourav (15%) K. Chadramukhi, KCH-1 & 2 (7%)
5	Chikamagalore	961	K. Jyothi (90%) others (10%)
6.	Bangalore urban	650	K. Jyothi (95%) KCH - 1&2)
7.	Dharwad	2,733	K. Jyothi (10%) K. Pukhraj (20%) & K. Jawahar (80%) & K. Surya and K. Gourav are picking up gradually in place of K. Jawahar
8.	Mandya	206	K. Jyothi (95%) others (5%)
9.	Others	108	K. Jyothi, (90%) K. Chandramukhi & others
	Total area	**39,236**	

Potato seed system and possibility of producing healthy potato seed in Karnataka

Supply of disease free seed is one of the main tasks of the Government. Seed is one of the basic inputs in potato production and it accounts nearly 40-60% of total variable of production costs. It has been estimated that, nearly 45000 to 50000 tonnes of certified seed will be required every year for raising of commercial crop in the state. As such there are no regular seed production programmes in Karnataka and the requirement is entirely depend on Northern States of country. Looking to the short supply of quality seed tubers, the middle man also tries to mix the commercial potatoes as seed tubers. There is no seed certification system in this supply chain. In view of the above, attempts are being made to find out the aphid free zones in Karnataka and produce disease free seeds. Hence a system has to be developed with Govt. agencies and CPRI authorities to produce desirable disease free seed (25-30 g size) after ascertaining in aphid free zones during winter. However, the suitable area for disease free seed production is very meager except Kemmannagundi of Chikamagalore district, where the aphid population is lower than ETL. Further efforts are required to produce disease free micro/mini tubers under *in-vitro* condition in collaborative approach with SAU's, State Govt. agencies and NGO's.

To overcome seed production problems, an alternate technology for growing potato with the true potato seed (TPS) has been taken up at Dharwad and it is expected to reduce the cost of seed material nearly 10 times. Looking to the efforts of potato Scientists of Dharwad "Centre for Technology Development, Bangalore has sponsored a scheme to produce TPS seeds in a large scale. This technology of using TPS and tuberlets is gaining importance and it is being demonstrated on farmers' field. But farmers are not following the important practices specially required for TPS seedlings hence the programme as remains unviable.

Possibilities of producing off-season potatoes for Seed purpose in Non-traditional areas of State

Under Southern dry Zone, potato is being grown in off season (*rabi*) as irrigated crop in places like Tumkur, Bangalore rural, Mandya, Chamrajnagar, Chitradurga, Haveri. Further, there is lot of demand and queries about possibilities of potato production from the farmers of Sirsi, Badami, Bagalkot, Gadag and Bidar districts. However the availability of quality potato seeds and suitable variety needs to be identified and recommended for above non traditional areas.

The soils of Dharwad and Belgaum are typical black cotton soils and best suited for taking up *rabi* potato crop to produce seed for next (Kharif) season. Due to continued efforts of potato scientists, Department officials and genuine seed potato traders, the area under potato cultivation is increasing during *rabi* season with supportive irrigation facilities.

To popularize cultivation of potato during *rabi,* several field days and farm visits were organised in previous years. The farmers who have takenup *rabi* potato cultivation have harvested bumper yields. As a result of this the farmers of Dharwad and Belgaum district have taken up *rabi* cultivation on a large scale (>200 ha) during 2006-07. The major variety is K. Pukraj and K. Jawahar in Dharwad district while in Belgaum it is K. Jyothi and in small pockets K. Badasha is also being grown during *rabi* season.

Similarly efforts are being made to popularize potato cultivation as a inter crop with sugarcane which is getting good response from the farmers, particularly from Belgaum district where paried row of sugarcane cultivation is being practiced of late.

Major Constraints for successful potato seed production in Karnataka

- One of the major hurdles for potato cultivation in Karnataka is non availability of quality seed tubers which have to be imported from Northern States, thus accounting for major cost of cultivation. The estimated seed requirement is 55-60 thousand tons which accounts for 4-5 crore rupees every year.
- Non-availability of certified seed tubers of recommended varieties.
- Sclerotium wilt in Northern Karnataka and bacterial wilt in Southern Karnataka are posing as major hurdle.
- In recent years *Spudoptera litura* is emerging as a new serious pest on potato which feeds on all parts of potato.
- Unscientific cultivation, improper plant protection measures and improper nutrition supply.
- Lack of improved storage structure in farmers field and in market yards.
- Lack of subsidized cold storage facilities.
- Non availability of semi automated / Bullock drawn implement for planting and for harvesting in black cotton soils.
- Production, supply and popularisation of mini / micro tubers to solve the problem seed availability.

Reasons for low productivity of seed Potato (Gaps and constraints)

1. Uneven distribution of rainfall and drought in the preceding moths/year.
2. Major problem in potato cultivation in Karnataka is availability of foundation seed tubers,
3. Imported seed from Northern India accounts for major cost (30.35 %).
4. Use of dormant seeds and commercial potato as seed material.
5. Under seed rate , over seed size, use of cut tubers for planting and Late sowing.
6. Use of traditional and old varieties (eg. Kufri Chandramukhi).
7. Lack of seed treatment measures to overcome the diseases
   a. *Sclerotium* wilt and bacterial blight etc. which are major problems in Karnataka.
   b. Non practicing IDM , IPM and INM measures.
8. Non practicing **'de haulming'** technique.
9. Lack of cold storage facility for storage of seed tubers.
10. Improper harvesting and post harvest handling.
11. Cultivation of unauthorized / not recommended varieties which may accelerate the Pest and disease problem.

Future strategies to increase productivity and production of seed potato in Karnataka

1. Development of high yielding varieties suitable to higher temperature regimes (heat tolerant) and long day conditions (*Kharif*).
2. Development of processing varieties for crop diversification.
3. Standardization of production of disease free tuberlets / minitubers under South Indian conditions during *rabi* season.
4. Standardization of intercropping systems with sugarcane, chillies, soybean etc..
5. To find out the effect of some of the trace elements, micronutrients and bio fertilizers on yield and processing quality of potato.
6. Management of major pest and diseases with organic amendments, bio-pesticides and bio-fungicides to minimise health hazards.
7. Extending the area of potato by introducing potato in non traditional areas in different seasons through adoptability trails and result demonstrations.
8. Development of suitable storage structures with a modification (Air circular methods) to local structures for medium, long term storage of potato.
9. Popularisation of ZECC for storage of potato in rural areas and in APMC yards.

Remedies to overcome low yield of potato in Karnataka

In potato, the potential yield is around 40-45 t/ha, which is being achieved in European countries and also in Northern plains of India. However, yield level in Karnataka is very low (10-13 t/ha). Hence to have a break through in targeting higher yields the following measures needs to be adopted.

I Long term measures

- Variety suitable to higher temperature and long day conditions (Kharif) needs to be identified.
- Efforts should be made to produce seeds tubers under South Indian conditions, so that at least for one season seed import from North will be reduced which results in reducing the cost of the seed and in turn production cost
- Efforts should be made to produce small seed tubers/ tuberlets (20-25 g) for avoiding use of cut tubers which also reduces seed costs.

II Short term measures

a. Seed factors

1. Quality and certified seeds should be made available to farmers through the intervention of Govt. agencies.
2. Efforts should be made for the availability of recommended variety (eg. Kufri Jawahar, Kufri

Pukraj, instead of Kufri Chandramukhi, which is no more exists in seed chain)

3. Strict quarantine measures should be implemented to curtail the introduction of unauthorized varieties.
4. Standardization of nursery techniques to reduce seed tuber rate and supply of disease free planting material.
5. Expansion of tissue culture studies for mini and micro tubers, plantlets and nodal cuttings followed by hardening techniques need to be followed.

b) Production Practices

1. Planting at right time i.e., between 1st to 2nd fortnight of June.
2. Seed treatment is advised with 0.2 % Ridomil M.Z + *Ttricoderma harzianum* (1%) for control of late blight and *Sclerotium* wilt.
3. Use of seed tubers of size 20-25 grams and use of just sprouted seed tubers.
4. Application of organic manures as per recommendations (25 t/ha) along with neem cake (300-500 kg/ha) for improving fertility and soil health.
5. Application of ammonium sulphate instead of urea at the time of earthing up for improving the quality of potato.
6. Inter cropping with sugar cane and other suitable crop combinations need to be developed.

c) Pest and disease factors

1. Use of virus free certified seed tubers for planting
2. For the control of late blight , shoot borers, mite and thrips, spray the crop with 0.2% Ridomil +0.2% Endosulphon + 0.2% Dicofol at 45 & 60 days after sowing
3. Treat the seed tubers with 1% T. harzianum bio- fungicide and follow the crop rotation with sorgum for control of *sclerotium* wilt.
4. Application of bleaching powder (25-30 kg/ha) and crop rotation with sorghum is to be followed in bacterial wilt affected areas.

d) Harvesting and post harvest factors

1. It is highly essential to follow **dehaulming** practices (cutting the upper leaves 15 days prior to harvest), so that periderm (outer skin) is properly set/ cured thereby tubers gets longer storability and minimum rottage. Dehaulming should be done based on varietal maturity after 75-90 days of planting.

e) Transfer of technology

1. Large scale demonstration of use of small size seed tubers & treatment with T.*Harzianum* + Ridomil MZ for control of seed borne diseases.
2. On farm and off farm demonstration of newly recommended varieties (K.Pukraj and K. Jawahar) along with dehaulming techniques

3. Demonstration of potato cultivation in new areas (Zone-9) and season (*rabi*) to achieve higher production and productivity of the state.

Government policies required for improvement of potato situation in the State

1. Subsidized price for seed tuber procurement.
2. Strict quarantine to control illegal seed entries from unknown sources.
3. Financial support of construction of low cost storage structure for small and marginal farmers.
4. Financial support of construction of storage units and small processing units in periurban areas.
5. Financial support for conducting research on prioritized areas (As indicated earlier).
6. Encourage contract farming and processors to enhance the income level of the farmers.

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Potato Seed Production Status and Constraints in Eastern Plains

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The states of Bihar, West Bengal, Jharkhand, Odisha, Assam, Chhattisgarh and Eastern Uttar Pradesh constituting eastern plains have about one fifth geographical area and one third of human population of India. About a million hectare of potato acreage forms only a fraction of net sown area (31.43 million ha) of this region but it constitute more than half of the country's potato acreage. This region is also characterized by dense population (604 persons/km2 compared to nation (382 persons/km2) and small size of holdings (marginal holdings comprises >80%). Despite being agriculture as the backbone of economy, productivity level is low in most of the states. According to planning commission this region has 69 numbers of economically most backward districts out of total 150 at national level. As a result of economic backwardness, rate of adoption of technology is slow. This is one reason why productivity of potato is much below the potential. This crop is an important winter season crop in many districts of the eastern plains. The potato must be given priority in this poverty and malnutrition ridden part of country as this crop produces higher edible dry matter and good quality protein than many other crops when per unit area and time is considered. The uniqueness of the crop being harvested even before maturity provides an excellent opportunity for horizontal expansion of potato acreage by diversifying predominantly rice-wheat cropping system of the region and helping in better utilization of resources.

Status of potato production in Eastern Plains

The Eastern plains contributes about half of the potato acreage (53%) and production (51%) of India. When we look at state wise scenario of this region, West Bengal is the leading state in respect of area (37.7%) as well as production (46.3%) followed by Bihar (**Table 1**).

Table 1. Area and production of different states of eastern plains

S. No.	State	2011-12				2012-13			
		Area (000 ha)	% of eastern plains	Production (000 tonnes)	% of eastern plains	Area (000 ha)	% of eastern plains	Production (000 tonnes)	% of eastern plains
1.	West Bengal	370	37.3	10700	49.2	376.75	37.7	9693.33	46.3
2.	Bihar	315	31.8	6104.3	28.1	315.40	31.5	6308.00	30.1
3	Assam	89.4	9.0	783.4	3.6	90.27	9.0	799.07	3.8
4.	Jharkhand	45.7	4.6	652.8	3.0	45.75	4.6	652.79	3.1
5.	Odisha	13.5	1.4	198.3	0.9	14.14	1.4	201.06	1.0
6.	Eastern UP*	157.2	15.9	3293.6	15.2	157.20	15.7	3293.60	15.7
	Eastern Plains	**991**	**100**	**21732**	**100**	**1000**	**100**	**20948**	**100**
	India	1,872.3		10,700		1,930.9		42,478.60	

* The value is of year 2010-11

When we compare productivity of potato in these states, except the state of West Bengal the whole region has productivity below the national average (**Fig 1**). Despite tremendous progress observed in the state of Bihar in recent years it is below the national productivity and much below the potential yield of the region. Other states like Odisha, Assam, Jharkhand and Chhatishgarh are much below in the rank and great potential needs to be harvested. These states contribute only 8% of the production from 15% of the potato area of the region.

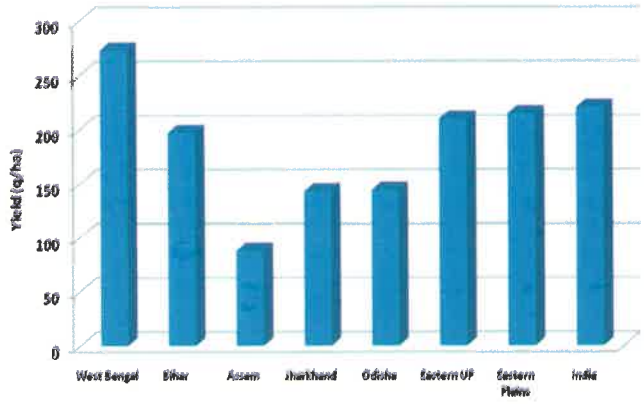

Fig. 1. Potato productivity of different states in eastern plains (mean of two years 2011-12 & 2012-13)

Requirement of potato seed

Healthy and quality seed is a prerequisite for raising a profitable potato crop. This has been proved on several occasions with sudden outbreak of diseases and low productivity in many pockets of region. Yield analysis of the performance of breeder seed developed by Central Potato Research Institute has indicated that the stocks are of very high health standards. It is just not possible to dispense with or go ahead to dream realization of plan and vision targets if availability of good quality seed is not ensured to every growers.

The area under potato in eastern plains is about one million hectare and the requirement of quality seed/certified seed to cater the need is about three million tonnes. Even if it is attempted to replace 1/3rd of the area with certified seed there will be a huge requirement of about one million tonnes of seed potato and consequently there will be requirement of about 4600 tonnes of breeder seed every year (Table 2).

Table 2. Quality seed potato requirement for eastern plains*

States	Area '000 ha	Requirement of different class seed (in '000 q) if 1/3 rd area is replaced with quality seed			
		CS	FS-II	FS-I	BS
West Bengal	376.8	3768	628	105	17
Bihar	315.4	3154	526	88	15
Assam	90.3	903	151	25	4
Jharkhand	45.8	458	76	13	2
Odisha	14.1	141	24	4	1
Eastern UP	157.2	1572	262	44	7
Eastern India	1000.0	10000	1667	278	46

*Seed rate 3t/ha, multiplication rate 6 times at every stage; area requirement for growing seed crops has not been accounted for

Projection for next decades

It is envisaged that India's potato production will be 69.39 million tonnes from 2.55 million hectare of land with a productivity level of 27.21 t/ha by the year 2030. Since, the eastern plains contributes about half of the production of country, it is clear that this region will have to shoulder its responsibility by increasing the productivity to a tune of 26.1 t/ha to achieve the production of 35.4 million tons from about 1.35 million ha land. This will demand for an increase in area and productivity by 38.9 and 31.0 %, respectively during coming two decades in the region (**Fig. 2**). With increasing area of the crop and high pressure to achieve still higher productivity ensuring high quality seed to every piece of land growing potato will be a necessity in coming decades. Therefore, about 1.35 mt of seed tubers needs to be available in the region by 2030 to realize the target productivity.

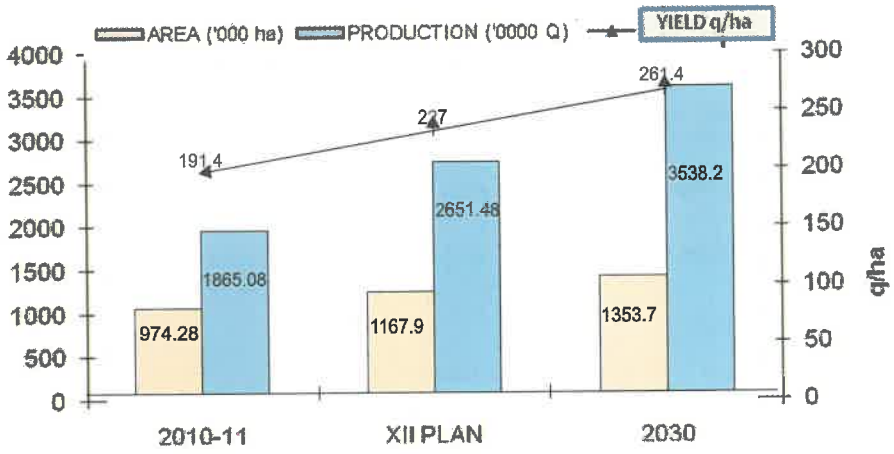

Fig 2. Area, production and yield projections for potato crop in eastern plains

Breeder seed supply to eastern states

Presently, CPRI produces about 2500 tones of breeder seed and a good portion of it is allocated to eastern plains (**Table 3**). However, it is very difficult to assure how much of it is really going to seed multiplication chain up to foundation and certified seed stages. This is very unfortunate situation as at one hand we are struggling hard to meet the good quality seed requirement of the country and on the other hand we are not able to convert the available breeder seed in to foundation I, II and certified seeds. There is need to have a concerted effort from government, public and private agencies to come together to work hard to overcome this deficit.

Table 3. Breeder seed supplied to different state government from CPRI

States	Breeder seed supplied (q)
West Bengal	769
Uttar Pradesh	8,057
Bihar	477
Chhatishgarh	339
Jharkhand	2
Total	22,996

Limitation of eastern plains

This region has huge gap in between demand and supply and most part of it have not being found suitable for production of breeder seed (**Table 4**) owing to limitation of short winter and narrow aphid free window, high prevailing temperature conditions causing faster multiplication of viruses and quick expression of symptoms as well as faster degeneration of seed stock. Many pockets of the region are having other inherent problem of soil borne diseases making area unsuitable for seed production.

Table 4. Suitability of eastern region for seed production

State	Type of seed	Remarks
Eastern Uttar Pradesh, Madhya Pradesh, Bihar	Nucleus, breeder, foundation, certified seed	Low aphids during October to mid January and no serious soil and tuber borne diseases.
West Bengal, Odisha, Chhatisgarh	Foundation and certified seed	High population of aphids, Bacterial wilt

Strategy for ensuring the quality seed potato

Strengthening Conventional Seed system: The formal seed channels aims at exploiting vector-free period and adopt appropriate strategies to control diseases, maintain health standards, follow copybook style of cultural practices and post harvest handling. There is, however, a limit to the contribution of Central Potato Research Institute to national seed production efforts owing to its mandate related to other research activities. Therefore, it necessitates sharing the responsibility to other public sector organizations like SAUs, State Govt. Deptt etc.

Infusion of Hi-tech for higher multiplication and better quality: Intervention of hi-tech seed production systems can reduce the burden of formal seed system. With the advancement in techniques, the seed produced through tissue culture is fast replacing the traditional system. Similarly the application of aeroponic system for potato production is not a dream for our countryman as the Central Potato Research Institute has made it possible and convenient to use it in our conditions. There is need to encourage these techniques which will helps in reducing the field exposure and ensures maximum quality standards with desirable size of potato tubers.

Strengthening the informal seed system: The private seed growers, seed traders and private seed companies constitute the informal seed production system and produce seed by following the seed plot technique. These are mainly scattered and not governed by strict rules and regulations hence, left with negligible accountability. The quality of this type of seed is not monitored by any government organization, unless it is registered under seed certification programme which is very less.

This is worthy to pay attention to this sector as the major quantity of seed is produced and supplied by these organizations. Through access to a schedule of defined activities undertaken under set rules and regulations, potato farmers can maintain health standards of the seed through numerous generations. There is need to strengthen this system by providing policy support, government interventions and by making available technical know how to those who are sincerely involved in seed business.

TPS technology for remote and poor Farmers: True potato seeds can supplement some quantity of seed requirement particularly in the pockets where farmers are resource poor, cold stores are not

available and seed plot technique is not a feasible option. The technology also becomes more economic as only small quantity of seed is required to cover a larger area. However, there are some limitations associated with this technology as produce of TPS cannot be used commercially in the same season and there is lot heterogeneity in the produced tubers.

Indentifying non conventional pockets for seed multiplication: Advanced Information Technology Tools (ITTs) like GIS and other are available to identify newer pockets where aphid free window where seed multiplication may be taken up after ground truthing. This can add tremendously horizontal expansion of seed producing area as well as to reduce the cost of transportation of bulky seeds from far away destinations.

To conclude with, eastern plains forms one of the important regions of the potato production with more than half of the country's potato acreage. Low productivity in this region has been mainly due to poor quality of seeds being used by majority of farmers. It is irony of the situation that majority of the areas are not suitable for good quality seed production therefore, remains as a net seed importer form northern part of the country. With higher targets of potato production in coming years, there is need to strengthen the seed system in the region as whole by strengthening the conventional seed chain system, infusion of hi-tech seed production systems including protected cultivation, identifying non-conventional pockets through GIS and also supplementing with TPS technology.

Research Initiatives under AICRP (Potato) for Augmenting Seed Production

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Potato being a vegetatively propagated crop is prone to a large number of seed borne diseases of which virus diseases are the predominant ones, hence good seed quality seed is of paramount importance. Therefore, production of healthy seed has been given priority and seed production technology has been developed as early as in the 1960s. This technology called the Seed Plot Technique (SPT) has been primarily responsible for the rapid productivity growth of potato in India. However, seed multiplication through SPT is a lengthy process since it involves field multiplication over many generations. Moreover, different agencies are involved in the multiplication of the seed at Foundation and Certified seed stages. Hence there is acute shortage of good quality seed. Studies were therefore undertaken at Central Potato Research Institute, Shimla to hasten the seed multiplication rate by using tissue culture and aeroponics techniques. This article outlines the scope for augmenting the seed multiplication systems through these techniques and the ongoing as well as to be initiated studies under aegis of the All India Coordinated Research Project on Potato.

Seed Plot Technique

This technology has revolutionized potato production scenario in the country. Viruses are transmitted by aphids, hence potato seed was produced in the high hills where aphid population pressure during the potato cropping period is low. The expansion of potato production in to the Indo-Gangetic plains increased the strain on the indigenous seed multiplication systems being practised in the hills. Therefore, aphid free window was delineated in the plains where seed production was undertaken by adopting suitable agro-techniques. The technique envisages raising the seed crop during the aphid free periods (Oct-Nov to Dec-Jan) in the northern plains big adopting a schedule of cultural practices which included pre-sprouting and use of medium sized tubers to hasten emergence and growth, frequent irrigations and high fertilizer application to mitigate the effect of high temperature at planting and early establishment of full crop canopy, mechanization for faster cultural operations in view of the short growing period and control of aphid vectors and diseases through regular sprays of chemicals and haulms cutting before the aphid count reached critical levels (20 aphids/100 compound leaves). The adoption of seed plot technique led to tremendous growth in cold stores for storage of the produce and enabled the use of the cold stored seed for autumn planting in the next season. As a consequence of the development of seed plot technique and increased cold storage of seed, potato tuber moth (PTM) got eliminated in the plains, tuber diseases were reduced due to early harvesting (at temperatures less than 28^{0}C) before the temperatures became detrimental, seed rottage decreased due to planting of physiologically mature seed and area under seed potato production increased almost 12 folds. Thus seed plot technique not only met the seed requirement but also led to higher productivity due to better seed quality and also decreased yield losses.

The potato acreage in the country is about 1.9 m ha which means that the seed requirement woud be about 4.75 m tons when computed at the rate of 2.5 t/ha. At present seed is produced largely through Seed Plot

Technique mainly in the northern Indo Gangetic Plains and transported to all the other regions of the country. Thus, there is a heavy demand for seed leading to monopolistic market tendencies and consequently leading to low seed replacement rate due to low availability and high cost. Different strategies are being evaluated under All India Coordinated Research Project (AICRP) on Potato to develop viable seed production systems so as to increase the availability of good quality seed. One of the methods envisaged is to find new areas for seed production through SPT. Therefore, studies on monitoring of aphid population and rate of degeneration were conducted at Kalyani in West Bengal, Chindwara in Madhya Pradesh, Deesa in Gujarat, Pune in Maharashtra, Hassan in Karnataka, Jorhat in Assam, Pasighat in Arunachal Pradesh, Bhubaneshwar in Odisha and Patna in Bihar for more than five years. The studies indicated that at least 9-10 weeks of low aphid pressure period is available at Kalyani, Jorhat, Bhubaneshwar and Patna. Thus appropriate package of practices for raising a seed crop in the low aphid pressure window are to be developed for these regions. Emphasis on delineating pockets free from soil borne diseases needs to be made and appropriate crop rotations and other package of practices need to be developed for these areas.

The conventional system of seed production through SPT has some limitations like, i) low rate of multiplication, ii) requires more number of disease free propagules in the initial stage and iii) requires many field multiplications of initial disease-free material (7 years). Tissue culture and aeroponics technologies have been developed to mitigate these problems and need to be integrated in to the seed production chain.

Microplant/microtuber based seed production system

These are two tissue culture based systems which involves raising of nodal cuttings from mother tuber(s) of a known variety free from all viruses and seed-borne diseases on semisolid MS medium in culture tubes or any other suitable containers following the standard procedure upto 10-12 cycles. *In vitro* plantlets are then hardened which are then transplanted on nursery beds in mixture of soil, sand and FYM (2:1:1) in rows at 30 x 10-15 cm spacing under insect-proof net house condition and all the recommended package of practices are followed. The seed produced from the microplants is known as minitubers (G-0). Minitubers weighing >3 g are planted in Generation-1 in the field during next season. Whereas, <3 g minitubers may be recycled once again in Generation-0 under controlled poly/net house conditions. The produce of G-1 is further multiplied in the field for one more generation (G-2) to get the basic seed for further multiplication in foundation and certified seed stages.

In the case of microtuber based seed production system the microtubers are induced on the microplants in controlled condition. In general, 15 to 20 microtubers weighing 50-300 mg are produced in each flask/culture bottles which are manually harvested. These microtubers are planted in the insect- proof net house or poly house as described above for the production of minitubers which are then further multiplied as described above.

The micro plants or microtubers produced through tissue culture needs to be planted in net houses to produce G0 or G1 stage tubers. The produce of G0 or G1 are multiplied in field to produce the basic seed material which is to be further multiplied in many stages before they are distributed to the farmers. Thus tissue culture can be integrated into the seed chain only at locations where seed plot technique is feasible. Moreover, net house space would be a limitation because the microplants or microtubers can be produced

in large numbers in the laboratory but they have to be planted in the net houses and thus large net house space would mean huge infrastructural investment. Under AICRP (Potato), tissue culture facilities have been created at Jorhat in Assam and Pasighat in Arunachal Pradesh and seed chains integrating the tissue culture produced seed into the seed system of the region are being developed.

True Potato Seed

TPS has the potential to be an alternative seed material in non traditional areas. However, its success lies in proper identification of target environment, development of appropriate technologies for use of TPS seed to produce seedling tubers and the use of seedling tubers inturn to raise a ware crop. Thus TPS technology is to be developed and standardized for specific environments only. The case of Karnataka is one example where its potential needs to be evaluated. The *kharif* season in some pockets can be used to produce TPS seed either through hybridization or selfed seeds. These TPS seeds can be used in niche areas like northern Karnataka to produce seedling tubers which inturn can be used to raise a ware crop in the next *kharif* season. Thus a workable cycle involving production of TPS seeds, raising of seedling tubers and raising of ware crop using the seedling tubers such that the requirement of cold stores is avoided needs to be worked out. To ensure success of TPS, studies would have to be carried out on producing large berries with strong and bold seeds, seedling tuber production technology which is simple and robust so as to produce large number of seedling tubers easily and technology to raise a good ware crop from seedling tubers. Studies on these aspects are being initiated at AICRP centres in the plateau *viz.*, Pune, Dharwad and Hassan.

Thus, alternate seed production systems have the potential to compliment the SPT, however, they need to be integrated into the seed production system for which location specific technologies would have to be developed through the AICRP on Potato.

Public-Private Partnership for Enhancing Potato Seed Availability in the India

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Potato is the 4th largest crop in India after wheat, rice and Maize. It produces highest food energy per unit of land i.e. 216 MJ/Ha/day. India is the 2nd largest producer of potato after China. This crop is going to play a very important role in ensuring food security of our country in future. In spite these facts the availability of quality seed in India is less which results very low yield per hectare. According to forecast, in 2030 our population may touch to 1.6 billion and during that time potato will be one of the imperative crop to provide the sufficient food to peoples of India. The Central Potato Research Institute (CPRI) also sets 70 Mln tons potato production target for the Country in 2030. But this can be achieved only if India will have sufficient quantity of quality potato seed.

The current situation of demand & supply of potato seed in Country is not exciting rather a concern. Presently potato production in India is around 40 Mln tons covering the 1.84 million hectare area. Its total seed requirement is about 3.5 Mln tons. But availability of seed is only about 1.1 Mln tons through various channels including Govt., Private agencies, seed growers etc and rest about 2.4 Mln tons seed is re-used every year. There is huge gap in the demand and supply of good quality potato seed and it is one of the main reason for lower per hectare yield in the Country i.e. about 19.5 tons/hectare. The potato production in India in 1990 was just 15.2 Mln tons with the area of 0.94 Mln hectare and presently we have crossed the production 40 Mln ton in 2011. It is a result of several meaningful efforts done by CPRI/Govt. / private agencies and farmers. In last 25 years CPRI has released so many potato varieties for a different purpose which is suitable in different agro climatic zones and crop rotations. CPRI is also producing reasonable quantity of breeder seed of various potato varieties. However state Govt. agencies & universities are supposed to take it further for multiplication to the level of certified seed and maintain the seed pipeline in the country as CPRI is more competent breeding agencies rather maintain the seed supply chain. If public sector agencies (specially state Govt.) multiply seed potato seriously & maintain the seed pipeline efficiently to certified level then we can cater the demand of Indian farmers for table varieties up to good extend. But supply of processing varieties is different story as their D-generation rate is very fast and we need to fill more breeder seed quantities in production system. But it is fact that our public sector agencies especially from State Governments have their own constraint in maintaining potato seed multiplication/pipeline. Some time they have also their own problems like availability of fund and resources etc. Once the breeder seed produced by CPRI is allotted to various state Govt. agencies or universities, it is observed that this does not multiply to the level of certified seed and disrupt the seed supply chain in between and consequently acute shortage of quality seed potato in the country.

In such environment the role of private sector is very important as they are better equipped in many ways. The public private partnership can fill this gap and maintain the seed supply chain in our Country properly. What CPRI can do, can create the quarantine production zone in the country and select private

sectors/ farmers who have full capability in terms of fund and better resources. However those breeder seed can partly be issued to the private players to take up the production for next level of F_1, F_2 and certified stage in selected zones. During this multiplication process CPRI can play the vital role as certifying agency and if they found any dilution in terms of qualities then they can reject the concerned fields. This proposed system can definitely ensure the proper supply chain of potato seed in India especially for table varieties. As far as processing varieties are concerned we need to produce more basic seed either from CPRI or from private labs. This project can be initiated as pilot project and once Govt. get the confidence and observe the better efficiency in this proposed system, then they can slowly increase the production area under PPP model. After production of seed to the level of certified, it can go to the various states according to their requirement. This system will bring more efficiency in basic seed production of particular variety as private sector has good understanding regarding future trend for particular varieties.

In addition to that CPRI can also allow involving private sector for advance stage trials of new releases to assess its performance and success in various agro-climate zones of our country. Since private sector have good reach among farmers so it can be widen the base of farmers/ corporate feedback from field trails. It has also been observed from last many years that some of the CPRI varieties could not get success as they could be. There are many reasons for this fact but one of the important reason is understanding of farmers regarding purpose of newly released variety and lack of knowledge of its agronomical practices. Once private sector is involved in production and supply chain of potato seed under PPP model then these problems can be rectified from system by using their extension team to educating the farmers in various zone of country. But we need to find out the way that during advance trialing stage seed pipeline must not be leaked out to anyone in the potato chain.

In recent past, few corporate like Technico & Pepsi Co. have set up and established the techniques of mass minituber production through tissue culture technology. These organizations are not only taking up the good work of CPRI further in terms of maintaining the seed supply chain in country but also trying their best to make Indian varieties popular in various Countries through export of minitubers in limited qualities. However they are also producing reasonable quantity of early generation seed of CPRI varieties and catering the demand of various farmers, institutions and processing sector in country. So looking in to their capabilities we can also enter in the agreement with them to multiply and maintain the seed pipeline of all promising varieties to be released in near future. In this regards variety protection low may also help to streamlining the seed pipeline in our country. The CPRI and GOI can also involve to the private sector and progressive farmers to set the research priorities and agenda in the country. This approach will lead to demand driven base breeding & research rather a general work. We also feel that if CPRI/Govt. focused mainly on research upon key issues, breeding of new generation varieties and further multiplication of seed hand over to the private sectors then it will be efficient and robust system of potato seed supply chain in the country. Secondly, CPRI can also strengthen their various testing facilities of potato crop and can provide this service to entire industry/ farmers on payment basis.

I am sure with this type of approach we can fully utilize the strengthen of Govt. and private sector along with farmers strength and can be developed a capable and efficient supply chain of potato seed in India which will help us to achieve the 70 Mln tons production target even before 2030 to ensuring food security in our country.

Pest and Disease Scenario Impacting Seed Production in the Tropics

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Potato is the third most important food crop in the world after wheat and rice. More than one billion people consume potatoes world-wide and it is part of the diet of half a billion people in developing countries. Because of its efficiency in producing highest dry matter, energy and edible protein per unit area per unit time, potato cultivation is expanding fastest in developing countries because majority have food deficit. However, this crop is highly susceptible to diseases and pests having a potential to drastically reduce its production. Therefore, sustainable potato production is possible only if the diseases and pests are kept under check, especially in tropics, where the weather is highly conducive for common pathogens like fungi, bacteria and viruses. Insect-pests also thrive equally well under the tropics. Although potato is affected by a large number of fungi, bacteria and viral pathogens world over yet all of them are economically not important in every region. Under Indian tropics viral diseases are the most important constraint for seed production followed by soil and tuber borne diseases and bacterial wilt. Among insects-pests, aphids and whiteflies, being virus vectors, are most damaging. Besides, leafhoppers and mites are also potential threats in the tropics. Most of these problems have been investigated for long under Indian conditions and suitable management schedules evolved. Major potato diseases scenario has been discussed in the following pages with special reference to Indian tropics.

Viral diseases

Prevalence and economic importance

Viruses have remained, and will continue to remain, as the most important factor limiting potato production throughout the world. In India, losses due to virus diseases in potato were estimated to the tune of 1.5-2 million ton per annum. More than 30 viruses infect potatoes of which actually seven are important in India. These are PVX, PVY, PVS, PVA, PVM, PLRV and PALCV (ToLCVND-potato). The losses due to viruses are usually quantitative but some cause qualitative as well. The losses in potato yield due to one or more virus (es) vary from low to very high. Infections of PVY and PLRV reduce the yields up to 60-80% while mild viruses, like PVX, PVA, and PVM depress the yields by 10-30% in infected plants. The potato viruses also affect seed quality and seed trade. PVS is the latent virus occurring up to 70-90% level in almost all varieties but cause severe infection only when combined with PVX and/or PVY. Virus-free seeds get rapidly re-infected during field multiplication without care or in areas unsuitable for seed production, due to high vector activity, etc. Due to mild viruses like PVX (or PVA and PVS/M), crop losses occur only when about 15% plants are infected. The common strains of PVX do not invoke symptoms or only faint symptoms when infecting alone. But combined infections of PVX+PVY/A(+M/S) have synergistic effects with heavy crop losses. If the seed stocks are not maintained well, or replaced frequently with fresh ones, the virus level reaches almost 100% within 3-4 successive crop seasons/years with almost half to one third yields.

Potato Viruses


PVA


PVX


PVY


PLRV


PALCV


PVM

All these viruses have been studied in detail at CPRI especially with reference to their symptom, transmissibility, epidemiology and host range. Detection of potato viruses and their elimination is central to the production of disease free seed. The CPRI has developed diagnostic methods for individual viruses based on indicator hosts, slide agglutination test, histochemical methods, ELISA, ISEM, NASH which were employed on large scale for their detection and elimination from the seed stocks. Recently more sophisticated techniques like PCR, RT-PCR, qRT-PCR have been developed at the institute which have revolutionized the production of disease free seed in the country.

Due to differences in the nature of spread/perpetuation of viruses, a number of indirect and direct measures need to be adopted for their management. Indirect control measures starting with healthy stocks serve the purpose better and help in maintaining the seed health for a longer period *viz.* multiplying the seed in vector free period/location, isolation of seed crop, sanitation, use of pesticides when essential, crop inspection for rouging/certification and dehaulming the seed crop as soon as the vectors cross the critical limit. Direct measures for virus control includes i) cultivation of virus resistant varieties ii) elimination of viruses from hybrids/varieties by apical meristem culture, and iii) rejection of infected exotic material through quarantine.

So far virus management is best achieved by preventing infection of seed potatoes hence reliable methods for virus detection have a great significance in the production of high quality seed potatoes. This calls for information on a) the type of virus (es), b) mode of their transmission, c) health standard of the initial seed material, d) weed hosts that can act as external sources of the viruses and e) factors affecting the build up of the vector and consequent spread of viruses.

Soil and tuber borne diseases

A large number of fungal and bacterial pathogens may cause three types of symptoms on plants/tubers-

blemishes on tuber surface, tuber rots and wilt/foot rot. These diseases are mostly caused by facultative parasites/facultative saprophytes which have a very long soil phase and are carried forward far and wide through soil and seed tubers.

Distribution: Some of soil and tuber borne diseases are restricted to specific agro-climates whereas others often occur throughout the country. For example, black scurf and common scab are almost ubiquitous in nature. Similarly, charcoal rot is prevalent in eastern and central plains where soil temperature at the time of harvest is high. Wilts are caused by both fungal and bacterial pathogens. Fusarium wilt, by and large, occurs in almost all regions while others are severe in certain pockets only. For example, *Sclerotium* wilt is endemic in plateau region comprising Maharashtra, Madhya Pradesh and Karnataka.

Charcoal rot

Selerotium rot

Black scurf

Common scab

Economic losses: Diseases like black scurf and common scab do not cause appreciable yield reduction but disfigure the tubers thereby reducing the marketability leading to low economic returns. However, these diseases are hindrance to seed production programme where their tolerance limits are fixed. Charcoal rot may cause 10-20% tuber rot in the eastern plains. Similarly, *Sclerotium* wilt is endemic in plateau region where it may cause crop loss of 5-25%.

The integrated disease management (IDM) approach is essential for managing soil and tuber borne diseases as these are carried over from one season to another through infected seed tubers and, to some extent, through soil. Following IDM package developed by the institute takes care of most of soil and tuber borne diseases:

I) Use disease free seed from reliable source, preferably from disease free area

ii) Treat seed potato with boric acid (3%)

iii) Follow crop rotation, use crops like cereals, millets and non-solanaceous crops in rotation with potato

iv) Follow hot weather cultivation in plains and plateau and cold weather cultivation in hills

v) In plains and plateau, harvest crop before soil temperature rises above 28°C

vi) Avoid injury to tubers and allow tubers to cure for 9-10 days after harvest

vii) Store the tubers in ventilated cold stores

Bacterial wilt or Brown rot

Bacterial wilt, caused by *Ralstonia solanacearum* is endemic in some parts of the country. Its incidence, however, keeps changing with the changing farming practices of the region. As a pathogen, *R. solanacearum* is highly variable consisting three races (race 1, 2 & 3) and several biovars. In India, only race 1 & 3 are documented for potato. The disease has a history of changing cropping pattern in some parts of the world. Potato cultivation was abandoned in Ranchi district of Bihar (now Jharkhand) due to severe bacterial wilt infestation forcing the farmers to shift to the cultivation of other crops.

Bacterial wilt

Bacterial wilt infected tuber

Distribution and losses

The disease is wide spread in tropical, sub-tropical and warm temperate regions. Bacterial wilt is prevalent throughout mid hills, plateau and peninsular region where soil and weather conditions favour bacterial survival. In India it is prevalent in all the states excluding Punjab, Haryana, western part of Uttar Pradesh and Andhra Pradesh. Wilt incidence and economic losses vary from place to place, season to season and the stage of crop damaged (before tuberization or after tuberization). Crop loss up to a maximum of 75% has been reported in potato in India.

Based on regional conditions, crops grown and agronomic practices followed, area wise bacterial wilt management schedules have been developed. In areas where source of inoculum is seed tubers, use of disease free seed+summer/winter ploughing is good enough to manage the disease. However, in areas where seed tubers along with weed hosts and left overs tubers form the source of inoculum, application of

bleaching powder and/or use crop rotations is essential besides the use of healthy seed.

Pests of potato

A great diversity of climate in our country allows a variety of pests to flourish and inflict damages to potato crop both in the field and the stores. Insect pests damage the crop by feeding on potato tubers in soil, feeding or sucking sap from foliage and feeding on potato tubers in stores. Accordingly, these pests can be grouped as soil pests, foliage pests and storage pests. Among all the insect affecting potato crop, sucking or sap feeders such as aphids, whiteflies and leaf hoppers are the most important because they not only physically damage the crop but also act as carrier or vectors of important viruses which limits prospects of healthy seed production. About 4500 species of aphids are known, of which 675 occur in India and mainly two of them viz. *Myzus persicae* and *Aphis gossypii* are important for potato because they transmit potato viruses in the field.

Aphids

Whiteflies

Whitefly (*Bemisia tabaci*) another sucking pest spread very important single stranded DNA geminivirus which cause apical leaf curl disease in potato. They acquire potato apical leaf curl virus (PALCV) by feeding on the infected plants for 2 to 24 hr and subsequently transmit these to healthy plants for the next 5 to 20 days in a persistent manner.

Mites (*Polyphagotarsonemus latus*) and leaf hoppers cause severe damage to early potato crop in Indo-Gangetic plains, certain areas in Maharashtra, Karnataka, Gujarat and western Uttar Pradesh.

Research efforts are required for developing new varieties with enhanced resistance to important diseases and pests both conventionally and molecular breeding. There is a need to keep vigil on the present day minor diseases and pests that may assume importance in future under climate change scenario.

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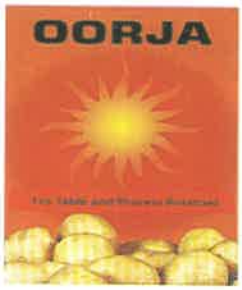

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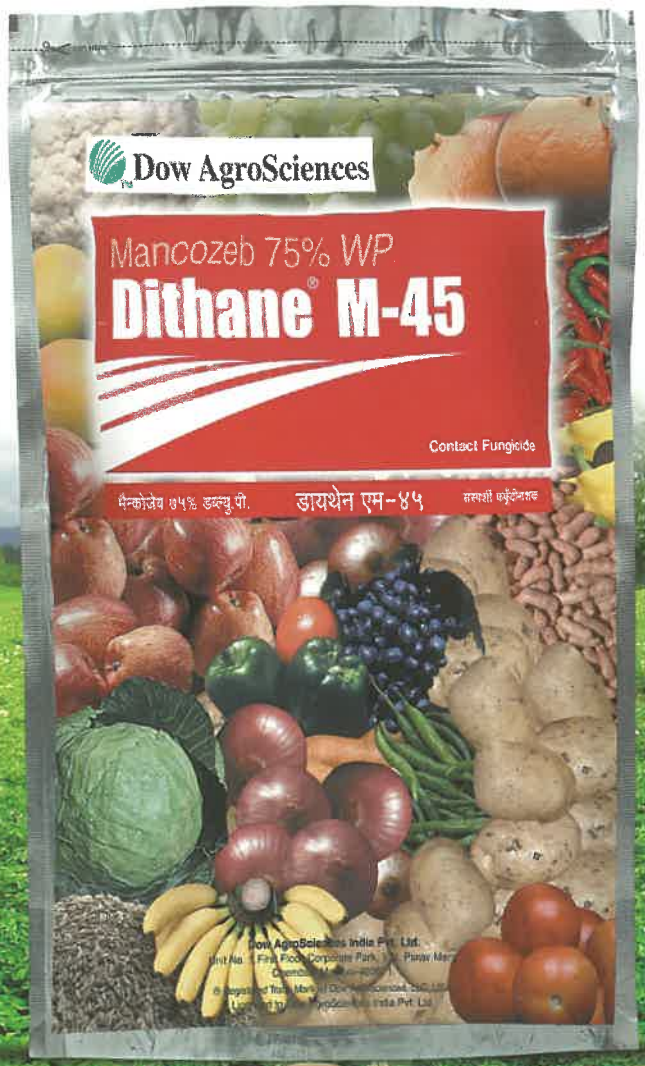

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