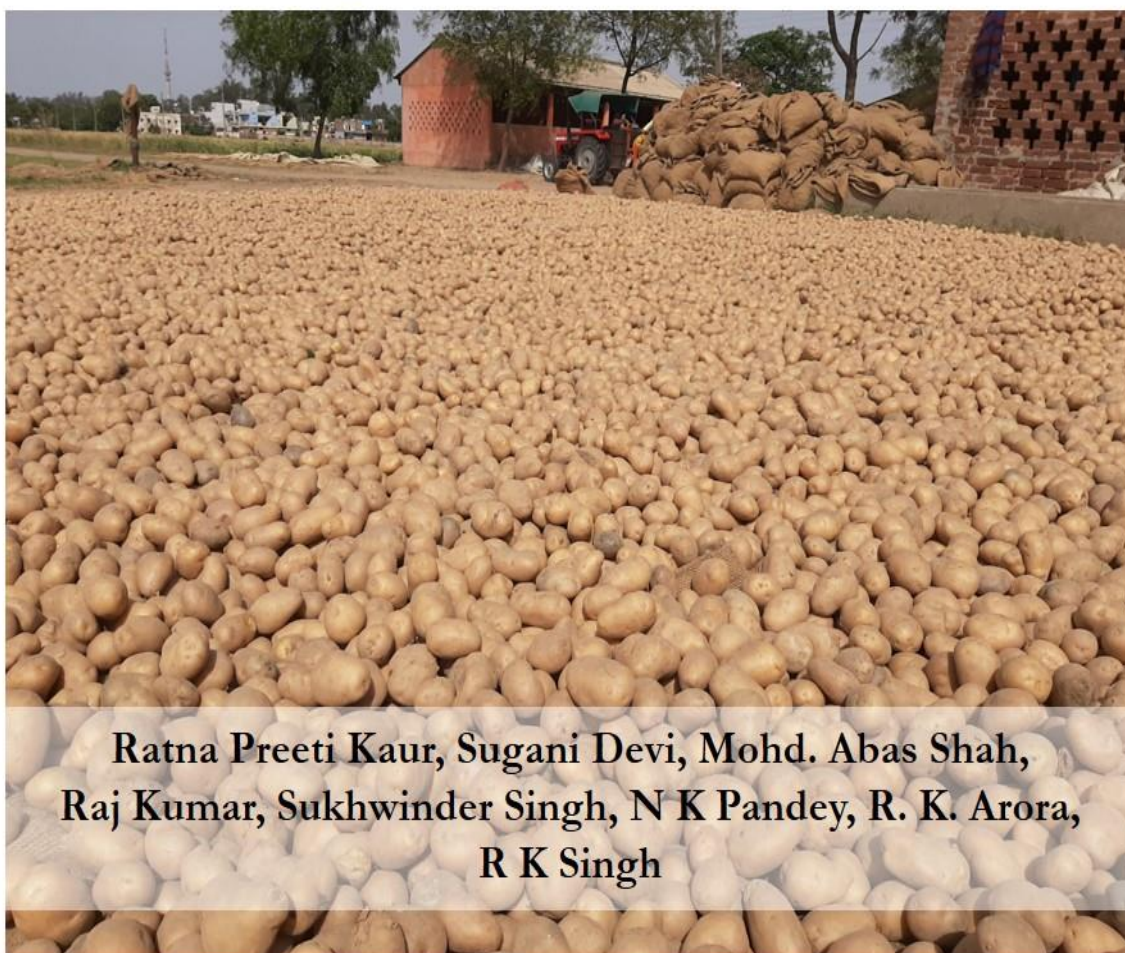


Technical bulletin

# Potato production scenario in Punjab with special emphasis on Potato seed production



Ratna Preeti Kaur, Sugani Devi, Mohd. Abas Shah,  
Raj Kumar, Sukhwinder Singh, N K Pandey, R. K. Arora,  
R K Singh



ICAR- Central Potato Research Institute,  
Shimla, 171001 (HP), India



## ***Preface***

Punjab has emerged as a major disease free seed potato producer and supplier state in India. This has become possible due to its unique environment which favors production of healthy seed potato during particular period in the autumn season together with the development of suitable technology developed by ICAR-Central Potato Research Institute and adopted by the farmers of Punjab. The short duration seed crop and higher returns associated with it has paid a rich dividend to farmers engaged in seed potato production. Punjab now meets a major demand of the healthy potato seed material for other potato producing states of India.

The technology of healthy seed potato production started with the development of seed plot technique developed by ICAR-CPRI in the early sixties. It has been modified over the years with evolving of better seed production technologies and virus diagnostics. There has been a gradual shift from the conventional system to the modern tissue culture-based technologies, rapid multiplication technologies employing Aeroponics, PCR based viruses diagnostics and improved protected cultivation systems.

The current bulletin “Potato Production Scenario in Punjab with special emphasis on Potato Seed production” is the first detailed bulletin which summarizes a brief history of Seed Potato Production in the state of Punjab, the status of formal and informal seed production systems prevalent in the state, different seed technologies involved in the production, the varieties cultivated, local consumption and the movement of surplus seed potato from Punjab to other states of India. It also focuses on the possibility of future improvements in term of the challenges posed by climate change, availability of cold store facilities, possibility of setting up of the specific Agri-Export Zone and many other issues related to potato seed production in Punjab.

Though some other bulletins on potato seed production have been brought out by Central Potato Research Institute such as ‘Potato in India in 1971’, ‘Seed Potato Production Manual in 2000’, ‘Certification of potato for seed and export in 2012’, and ‘Seed production Techniques (Principles and Applications) in 2017’ but the current bulletin gives an exclusive and an up-to-date account of the seed potato production specifically for Punjab which is now a major hub of seed potato production in India..

The authors: Ratna Preeti Kaur, Sugani Devi, Mohd. Abas Shah, Raj Kumar. Sukhwinder Singh, N K Pandey, R. K. Arora and R K Singh have made good efforts in compiling this information. We hope that this bulletin will serve as a reference point for potato producers, the researchers and the administrators who are involved directly or indirectly in the production and movement of high quality seed potato in and out of Punjab

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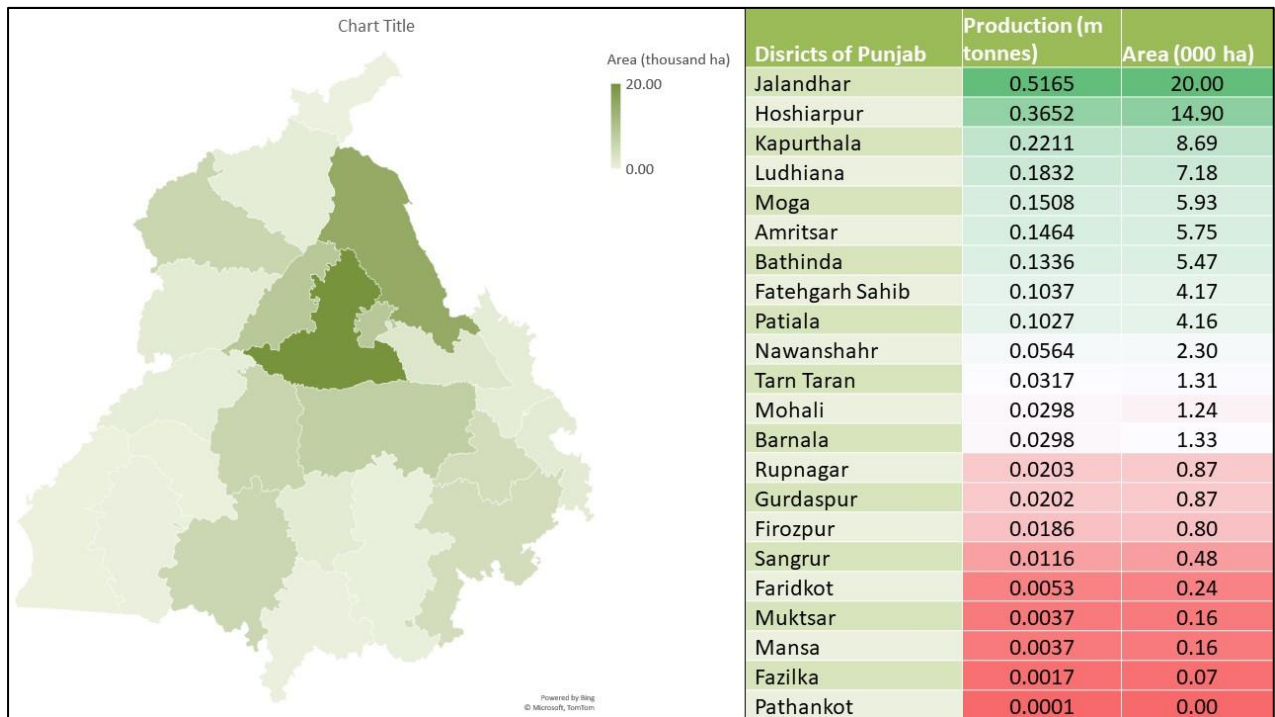
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## ***1. Introduction***

India is the second largest producer of potato in the world after China. It produced 48.6 million tonnes from an area of 2.18 million ha with a productivity of 22.30 tonnes/ ha during 2016-17 (FAO). A closer view of the data revealed a phenomenal increase in area by 9 times; a 30-fold increase in production and tripling of productivity during last five-decades since 1949-50 when the potato crop was grown in merely 0.89 % of India's total gross cropped area.

Punjab is one of the major agriculture state of India, with an area of mere 1.57 percent of the India's total geographical area, the state of Punjab contributes 12 percent to the nation's 234 million tons of food grain, and nearly 40 and 60 percent of the wheat and rice food stock buffer maintained by the nation's central pool and operating of public distribution system for the poor (Tiwana et al., 2007). Punjab stands 6<sup>th</sup> in total potato production of 2.57 million tonnes, recording the third highest productivity (26.10 t/ha) from an area of 0.98 lakh ha in 2017-18 (Horticulture Statistics Division, Department of Agri. & Cooperation). Its unique agro-climate has enabled it to evolve as the major disease-free seed producer of the country, which meets 90% of the total disease-free potato requirement of the country (Status report Department of Horticulture, Punjab). The state especially its northern Doaba region, enjoys optimal climate and soil parameters for growing healthy potato tubers with lower rates of infection. Punjab supplies about 110 lakh quintals of potato seed to states like Uttar Pradesh, West Bengal, Bihar, Madhya Pradesh, Gujarat and other potato producing states. Short duration and higher returns from the crop makes it more favorable for the farmers of Punjab economically. Potato is grown in all 22 districts of Punjab (Fig. 1). The top five districts of the state in terms of potato area are Jalandhar, Hoshiarpur, Kapurthala, Ludhiana and Moga (Punjab Horticulture, Horticulture Statistics at a Glance, 2018 Government of India, Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare, Horticulture Statistics Division).



**Figure 1: Potato production in the 22 districts of Punjab based on average production and area over the last ten years (2007-2017) (Compiled from Department of Horticulture statistics available online at <https://punjabhorticulture.com/Documents/Crops/Vegetable/> )**

Timely adoption of the policies related to quality planting material along with ICAR-Central Potato research Institute led seed research programme have played a key role in increasing the overall productivity of the crop in the country. The institute formulated a seed plot technique in 1960's which was adopted with much zeal in Punjab by its progressive farmers, leading to the production of large quantities of disease-free quality seed for the rest of the country which resembled in a perpetual boom in this sector. Punjab gained much prominence over the years in supplying large quantities of quality seed potatoes to the states of West Bengal, Karnataka, Bihar, Gujrat, Himachal Pradesh, Assam and other states to be delineated as the seed bowl of the country. Mean time the seed production technologies have gradually improved from conventional to hi-tech and from a disorganized to a strong sector backed by public regulatory organizations which monitor Breeder and different seed stages. Seed Potato industry has brought huge



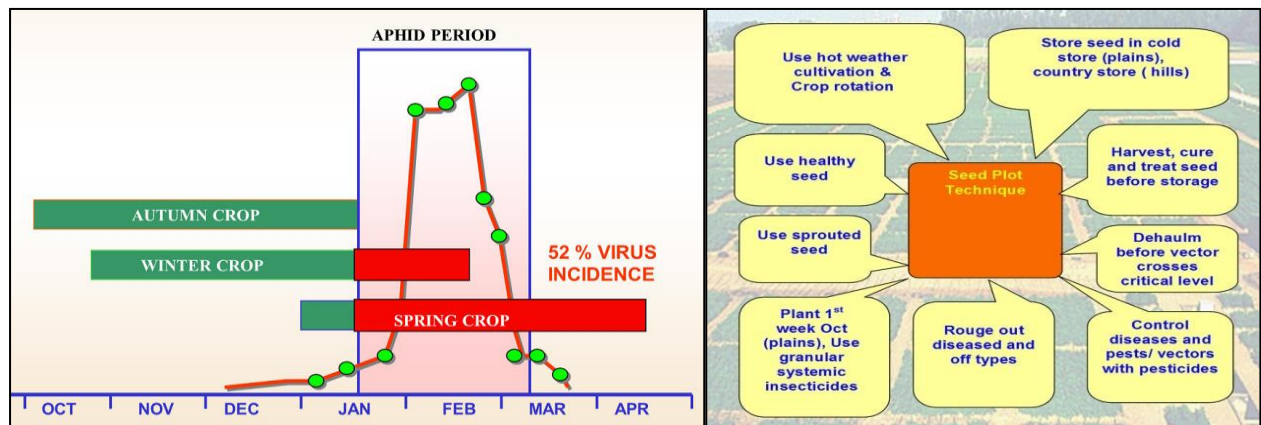
profitability to the farmers of the state. This article traces the developments of seed potato production in Punjab and attempts to get an insight into the present-day scenario with respect to the issues and the ways to sustain seed potato production and profitability.

## **2. *Potato Seed production in Punjab:a brief history***

Potato is a vegetatively propagated crop, which is prone to degeneration over the years on account of accumulation of viruses and mycoplasmas in the tubers, leading to drastic reduction in yields over a period of four to five years. The ideal condition for disease free seed production requires low vector population (aphids and white flies) where good quality of seed can be ensured. Due to this constraint, before 1960, the seed potato could only be cultivated in hills which had low vector population. But due to limited area and low productivity in hills, the quantity of the seed produced in hills was not adequate to cater to the requirement of planting material in the vast area of the Indian plains. Other issues like unsuitable physiological age, dormancy of tubers, long distance transport, soil and tuber borne pathogens in plains were other constraints. Dormancy of tubers often led to late planting of crop in plains and exposure to the high-vector population resulted in degeneration of the seed. Further, potato varieties prevalent at that time were more suited to long day conditions of the hills as compared to the prevailing short-day conditions of plains.

Development of the seed plot technique was based on a survey of the population of the aphid *Myzus persicae*, which is the major virus vector of potato in the North-Indian Plains. Its population remained primarily absent or extremely low in the region from October to December, which was sufficiently long to grow healthy seed crop. Results of this survey turned out to be a path breaking discovery for the seed plot technique (Fig 2), which revolutionized seed production in India. Now the successful seed crop could be grown from end of September to January, with a proper management schedule. It was reported that the seed plot technique enabled growing of the seed stocks even healthier than that produced in Europe (Garg *et al.*, 2008). Besides, the soil of

Punjab is free from serious pathogens and pests particularly of wart disease (*Synchytrium endobioticum*), cyst forming nematodes (*Globodera pallida*, *Globodera rostochiensis*), non-cyst forming nematodes, brown rot or bacterial wilt (*Ralstonia solanacearum*) and Black scurf (*Rhizoctonia solani*) making it suitable for potato seed production.



**Figure 2: Seed Plot technique in Potato developed by ICAR-Central Potato Research Institute depicting the vector dynamics in the North western plains and the crop management for seed production in the region**

A group of progressive farmers of the state quickly identified its immense potential and rapidly embraced the seed plot technology, establishing Punjab as a seed bowl of the country. There was a linear increase in area, production and productivity during the first three decades (1958-59, 1968-69 and 1978-79) of its adoption. The crop has thence witnessed a steady growth from mere 9,000 hectare in 1960 to 64,000 hectares by the year 2000, which was the biggest jump after rice and wheat.

This development created tremendous opportunity to seed growers in Punjab to provide seed to rest of India which faced severe limitation of production of quality seed at places with high vector population. Since the harvesting of potato in Punjab is completed much before the planting time in the southern and eastern states of India, it ensured a good supply of seed material at their time of planting. The crop also provided an alternative to the wheat-rice cycle prevalent in the state. Besides, under the intensive cultivation prevalent in Punjab, early bulking varieties of potato bred by ICAR-Central Potato Research Institute, Shimla could easily be planted between rice and



wheat, yielding higher returns. Amidst all these and the much-needed crop diversification in Punjab due to depleting water resources and failing monsoon, potato found a suitable abode.

### ***3. Punjab Agriculture profile***

Before the partition of Punjab in 1947 it was factually the “land of five rivers” located at the confluence of five rivers Beas, Chenab, Jhelum, Ravi and Sutlej. However, after the partition, it now has a total geographical area of 5.03 million hectares out of which 4.23 million hectare is under cultivation (about 84%), the area is just about 1.5 % of the total geographical area of the country. Even with this small proportion of area, it contributes approximately 50-55% wheat and 35-40% rice to the central pool. With its subtropical location there is a wide variation in climate and soil. Punjab experiences three main seasons: hot season, rainy season and cold season. The major rainfall is received during mid-June to September from south eastern current of summer monsoon; and also during the month of December to March, which are beneficial for Rabi crops. Variation in the rainfall pattern, with the south-western districts receiving 122 mm rainfall to the sub-mountainous districts receiving more than 863 mm rainfall is observed. Groundwater sources of irrigation are utilized in addition to rainfall, which has led to their over exploitation over the years due to intensive agriculture in the region (Baweja *et al.*, 2017). June is the hottest month, with temperature ranges between 40 –45 degree Celsius, while January is the coldest month, with temperature falling below zero-degree level. The occurrence of frost during December and January have been reported to damage fruits and vegetable crops like guava, potato etc. The soil pH varies from 8 to 8.7. Generally, the soils are low in Nitrogen, Zinc, low to medium in phosphate and rich in Potash. There is a huge variation in the soil, which is primarily alluvial but ranges from sandy to sandy loam. The plains of Ravi, Beas, Sutlej and Ghaggar rivers have medium to heavy textured soils which are very fertile. The state has hilly areas in the north covering 20 per cent of the total area, alluvial plains in the centre covering 55 per cent of the total area and sandy region in the south-western part of the state. The state has been divided into three

agro-climatic zones namely sub-mountainous zone, central zone and arid irrigated zone on the basis of homogeneity, rainfall pattern, cropping pattern, etc. (Fig 3), each having different cropping patterns and growing periods.

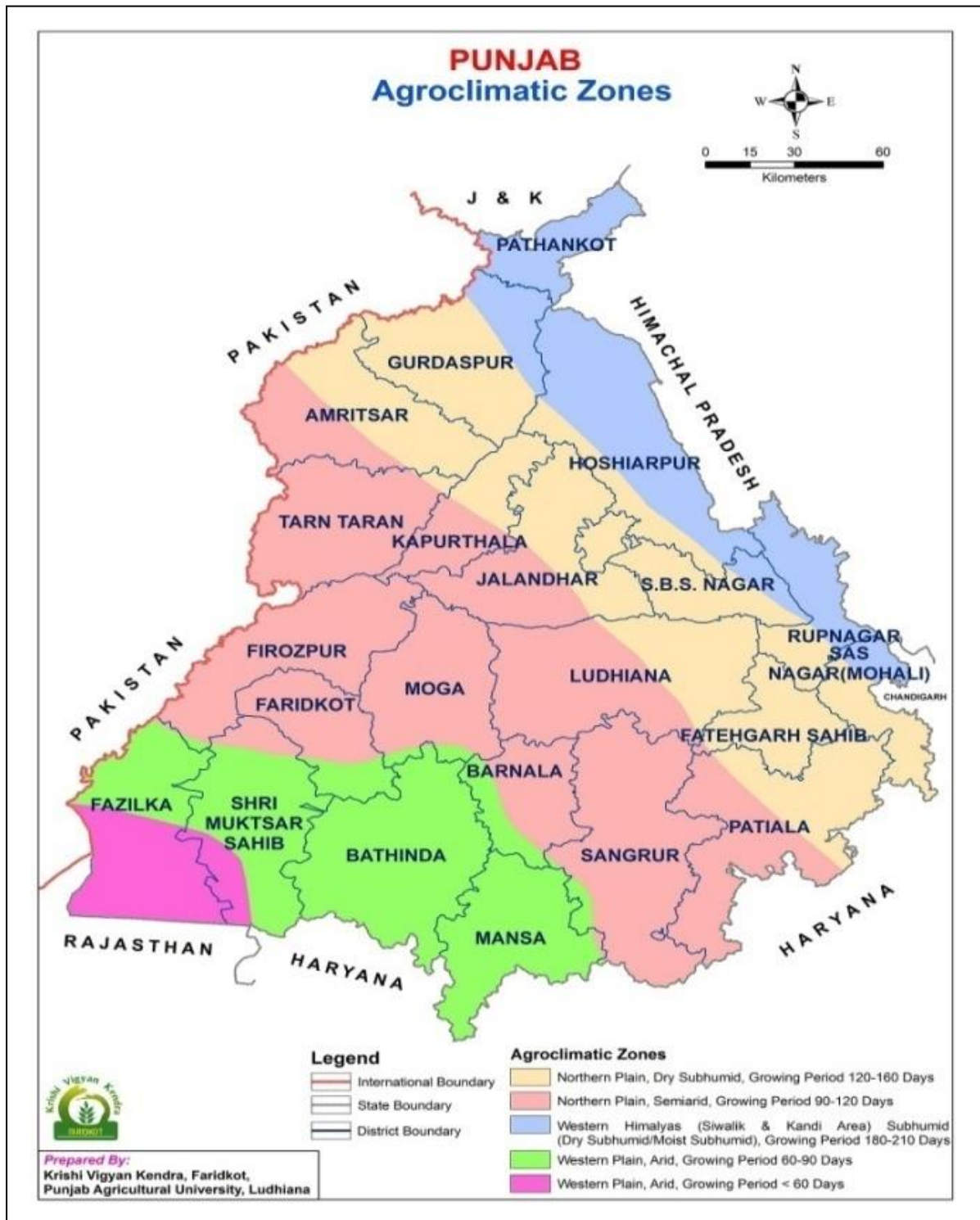


Figure 3: Agro-climatic zone s of Punjab state. Source: Krishi Vigyan Kendra, Faridkot

With the cropping intensity of 188, agriculture is the way of life and more than 65% of its population depends directly on agriculture. Agriculture is deep rooted in the thought, outlook, culture and economic life of the state and continues to control all strategies for planning socio-economic development of the state. The state is placed strategically on the map sharing an international boundary with Pakistan on one side and state boundaries with Rajasthan, Haryana, Himachal Pradesh and Jammu and Kashmir on the other side. This provides ample opportunity for supply of agriculture produce not only to its neighbouring states but also for the export of the produce.

The agricultural progress made in Punjab state is unparalleled in the history of the world agriculture. Dominating agrarian structure, consolidation of holdings, development of irrigation infrastructure and hardworking peasantry led to rapid early progress. Adoption of new agricultural technology in mid-sixties backed with favourable agricultural policies together made the state surplus in food grains and a model of India's successful green revolution strategy. The land use pattern of the state over the years from 1970-71 to 2014-15 based on percent of gross cropped area has been depicted in Table 1. The table gives a clear indicative of the shifting of agriculture from oilseeds, pulses, maize and other horticulture crops to rice over the years. The state emerged as a major food grain producer of the country mainly wheat and rice.

**Table 1: Shift in cropping pattern in Punjab (1970-71 to 2012-13) (Percent to Gross cropped area)**

Crop	1970-71	1980-81	1990-91	2000-01	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2014-15
Wheat	40.49	41.58	43.63	42.92	44.31	44.57	44.72	44.53	44.63	44.69	44.72	44.61	44.54
Rice	6.87	17.49	26.86	32.89	33.15	34.57	35.58	35.85	35.61	36.2	36.3	36.85	37.73
Cotton	6.99	9.6	9.34	5.97	7.69	6.66	6.49	6.13	6.52	6.11	6.13	5.27	4.2
Maize	9.77	5.65	2.51	2.08	1.96	1.91	1.76	1.69	1.65	1.66	1.67	1.6	1.61
Potato	0.3	0.59	0.31	0.75	1.14	1.04	1.05	0.81	0.89	1.02	1.01	1.13	1.16
Sugarcane	2.25	1.05	1.35	1.52	1.37	1.02	0.76	0.89	1.01	1.04	1.13	1.23	1.17
Pulses	7.29	5.04	1.91	0.68	0.34	0.28	0.24	0.25	0.25	0.25	0.24	0.17	0.25
Total foodgrains	69.18	68.82	75.55	79.05	80.03	81.58	82.52	82.52	82.35	83.01	83.1	83.35	84.29
Total oilseeds	5.2	3.52	1.32	1.01	0.76	0.76	0.79	0.71	0.66	0.65	0.6	0.59	0.61
Others	20.84	15.48	12.77	12.18	9.28	9.19	8.61	9.14	8.78	8.37	8.2	8.55	8.75

Source: Statistical Abstract, Punjab

Selected agricultural growth indicators depicted as Compound Annual Growth Rates (CAGR) with respect to potato production in the state are presented in Table 2.

**Table 2: Compound Annual Growth Rates (CAGR) of potato in Punjab in respect to area, production and yield in Punjab state**

1971-72 to 1980-81			1981-82 to 1990-91			1991-92 to 2000-01			2001-02 to 2015-16			1971-72 to 2015-16		
A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
11.75 ***	17.59 ***	5.11 ***	2.77 ns	2.24 ns	0.49 ns	14.14 ***	13.93 ***	0.01 ns	2.12 ***	4.70 ***	2.50 **	3.12 ***	4.07 ***	0.88 ***

Source: Statistical Abstract, Punjab, A: Area, P: Production and Y: Yield\*\*\*, \*\* and \* significant at one, five and ten percent level of probability, respectively

Horticulture crops are generally more remunerative as compared to the cereals due to shorter duration and higher returns. This is the major reason for the promotion of horticulture in the state in recent years to boost farmers income, besides the emergent urgent need of crop diversification in the face of declining water table. With an annual growth rate of 6%, horticulture contributes about 12.43 per cent to total agricultural GDP of the state, from just 4.83 % of the area (<http://punjabhorticulture.com>). Presently, area under Horticultural crops in Punjab State is 380750 ha. out of which 86670 ha. is under fruits, 273250 ha is under vegetables, 2100 ha is under flowers and 18730 ha is under spices and aromatic crops.

Potato is one of the most important horticultural commodities in the state. The per cent area under potato has increased five-fold during the period from 1970-81 to 2015-16 and increase in production of potato during this period is 9.86 times. However, more significant development has been its emergence as the most important disease-free seed producer in the country, which has led to the emergence of India as a second largest producer of this commodity in the world.

The average net return based on a 2016-17 study, for potato cultivation in Punjab has been reported to be Rs 24,172 per ha with a 1.43 benefit cost ratio valued at 2006-07 prices and

represented present values of respective parameters. The cost of seed in this study was reported to be 57% of the total cost of cultivation (Sidhu *et al.* 2009).

#### **4. Present status of potato in Punjab state**

With the total area under vegetable crop standing at 2.73 lakh ha, potato occupies about 1.02 lakh hectares accounting for 37.36 % of the total area under vegetables, yielding a production of 27.16 lakh MT in 2018-19 (Punjab Horticulture Department). In case of potato, consumption/person/day (g) in urban and rural areas in Punjab has been reported to be 112.5 and 105.49 respectively (NHRDF, 2015).

Out of the total potato production in Punjab, 60% is as seed which is utilized for its own requirement of seed potato (30 lakh quintals) and also for supply to other States in India (about 110 lakh quintals) representing 20% of the national potato seed requirements. The rest is either consumed as ware (30 lakh quintals) or is a surplus for trade and exports (40 lakh quintals) (Report of European Commission of Health and Consumers Directorate). The total requirement of the seed potato within the state in 2018-19 was estimated to be 4.12 lakh MT, and the requirement as received from the other states was 12.18 lakh MT amounting to total of 16.30 MT requirement. Similarly, the requirement of ware potato for the state itself and the other states in the period was 4.84 MT and 6.02 MT respectively (Punjab Horticulture Department Status Report).

The robust seed technology research and innovative quality seed production programme initiated by public and private sector has played a strong role in boosting the potato production revolution in the country. The region has thence emerged as the major seed producer in the country with “*Punjab aalu beej*” having gained a geographical indication (GI) status, in lieu of its high quality (filed by PAU, Ludhiana in 2017). The formal and informal seed system is prevalent in the state. The availability and requirement of quality/ certified potato seed in Punjab (lakh quintals) has

been tabulated in Table 3 along with the seed produced by the public and private seed producers. The private seed production accounts for more than 60% of the total seed production of the state.

**Table 3: Availability and Requirement of quality/ certified seed in Punjab (lakh quintals)**

	Requirement	Public	Per cent of total	Private	percent of total	Total
2015-16	28.64	6.91	26.47	19.19	73.53	26.1
2016-17	36.53	7.26	26.79	19.82	73.21	27.09
2017-18	38.22	11.02	36.88	18.86	63.12	29.88

(Lakh quintals. Source: Department of Agriculture Cooperation and Farmers Welfare)

There are 8 state Government potato seed farms that produce and supply approximately 300 MT high quality seed annually located at Dhogri, Malsian, Khannaura, Gurdaspur, Sohal, Bir Chirk, Harnam Singh Wala (Punjab Horticulture Department).

#### ***4.1. Prevalent seed systems in Punjab***

A "seed system" can be broadly defined as "an interrelated set of components including breeding, management, replacement, and distribution of seed" (Thiele, 1998). An evaluation of the prevalent seed systems in Punjab revealed that both the formal and informal seed systems were prevalent in the state. Based on an estimate the formal seed system contributes only 20% of the total seed production in India, used by growers whereas the other 80 % is contributed by the informal system (Kadian *et al.*, 2007). In Punjab domestic certified seed is used in only 1% of the areas cultivated for the production of ware potatoes. The remaining 99% is covered by TLS (Truthfully labelled seed) produced exclusively by private seed producers or through farm saved seed. Seed is regularly renewed by the annual introduction of certified or Truthfully labelled seed (TLS). The need for potato seed is covered either by certified "Government grade" seed or by TLS purchased from producers who assured sourcing of certified seed of "Government grade" quality. Kadian *et al.*, 2007 estimated that less than 25 percent of farmers were able to obtain healthy seed as and when needed to replace their debilitated stocks, suggesting that the seed



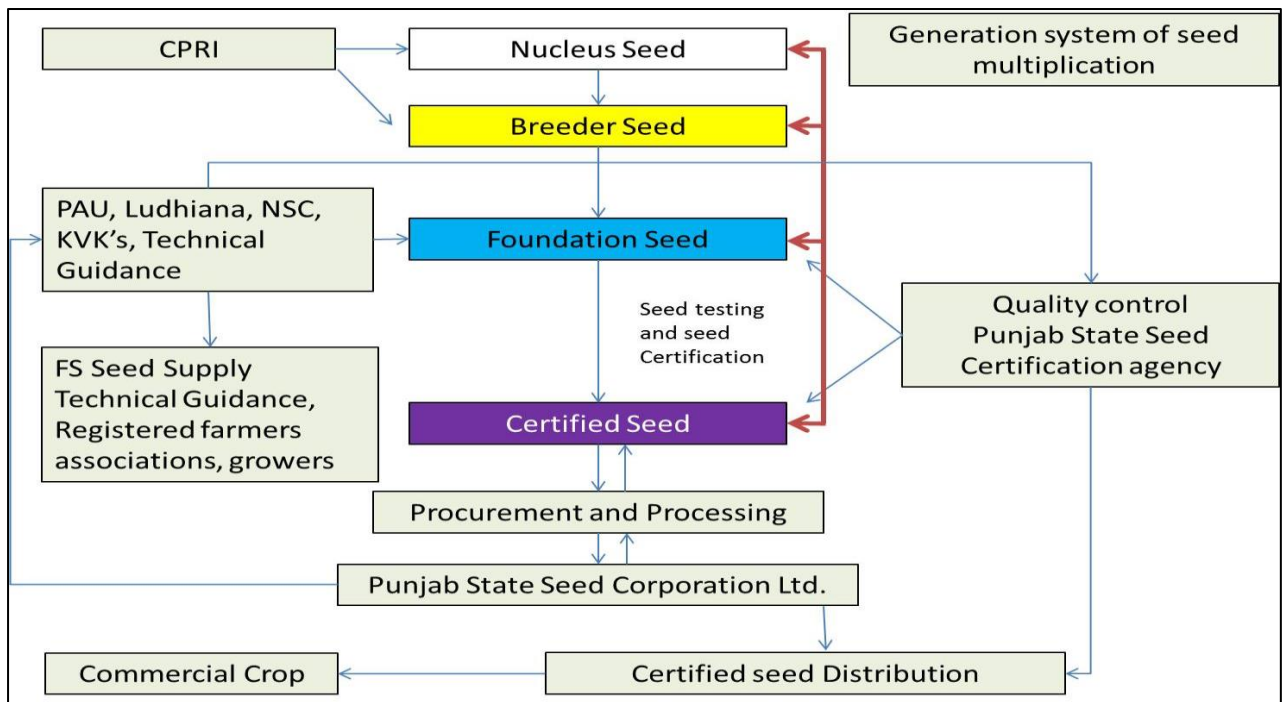
system remains a constraint to further expansion of potato production in India, though not to the same extent as in many other tropical countries where potato is an important crop. This has led to indirect promotion and prevalence to the informal seed systems in India.

#### ***4.1.1. Formal seed production system***

The formal seed production system in the country holds ICAR- Central Potato Research Institute, Shimla at the focal point for introduction of breeder seed of potato varieties and for the introduction of newly developed or acquired varieties. These are supplied to the government agencies active in the region like Punjab Horticulture Department, National Seed Corporation (NSC), National Horticulture Research and Development Fund (NHRDF), Punjab Agriculture University Ludhiana, based on the allotment by the Ministry of Agriculture Cooperation and Farmers welfare, generated on the basis of indents submitted by the different government agencies and registered growers. The allottees are then responsible for multiplication and distribution of certified seed of the allotted breeder seed on their own farms or through their registered growers following the four-stage seed production system.

In Punjab like any other state the "Basic" or "breeder" seed supplied by ICAR-Central Potato Research Institute, Shimla is accompanied with a certificate and an appropriate tag, which is purchased and multiplied into "foundation seed (FSI and FSII)" and "certified (CSI and CSII)" seed and made available for distribution to farmers after due inspection. Seed is also supplied to registered farmers associations like JALPO, JPGTAJ etc. or to growers who have signed an MOU with the institution regarding multiplication of Breeder seed as Foundation before its sale as certified seed. The seed multiplication is closely monitored by the Punjab State Seed Certification Agency (PSSCA), Mohali, Punjab for inspecting the crop with little or no incidence of disease or pest infestation. It is one of 20 seed certification agencies operating in India which regulate seed quality. The issuance of a potato seed certificate is accompanied by certification tags to be

enclosed in or attached to the packaging material. PSSCA also has an advisory and extension role and makes suggestions for corrective action to be taken by farmers on a case-by-case basis. Therefore, the "formal" system in Punjab refers to seed tubers produced and distributed by state-sponsored institutions (possibly with some involvement of the private sector and/or non-government organizations). The role of the stakeholders involved in formal seed potato production has been depicted in fig. 4. Depending on local needs, farmers might sometimes, continue multiplying foundation seed into subsequent generations of seed which can still qualify as certified, e.g. certified 1/2/3 (Kadian *et al.*, 2007), based on the number of years it was multiplied.



**Figure 4: Formal seed production system, certification and distribution in Punjab and role of stakeholders in quality seed production**

#### 4.1.2. The "Informal" Seed System

The informal system prevalent in Punjab comprises of the production and distribution of seed by farmers themselves. These comprise of two kinds of seed. The first one is where the farmers generally maintain their own seed stocks and use it to plant it on their own fields. The other popularly referred to as the Truthfully labelled seed (TLS) originates from stocks of certified seed

which have been grown using the seed plot technique, for up to four growing periods and stored for 6-7 months during the warm season under refrigerated conditions. An internal inspection system like that applied to produce certified seed is in place to check that varietal characteristics and appropriate hygiene conditions of the produced TLS is maintained. However, there is no official or other external verification of the TLS production, and is more dependent on the credibility of the seed producer.

However, sometimes the farmers need to procure seed from external sources due to losses due to disease or pest infestation or for replacement of deteriorated seed stocks and to acquire new varieties (Tripp, 1997). The farmers in this case purchase seed from farmer associations or from other farmers known to them. There is no proper verification of the quality of the tubers and disease status of tubers in this kind of purchase. This system is also prevalent in Punjab among the farmers generally growing table potatoes for wholesale sale.

The private seed producers have had a presence in seed production since the very inception of the seed plot technique, many of them have developed major seed producing companies and farmer associations, producing large quantities of truthfully labelled seed, which is sold in bulk to other potato producing states.

#### ***4.2. Prevalent seed production technologies in the state of Punjab***

Presently two kinds of seed potato production systems for production of breeder seed are prevalent in the state *viz.* the conventional system and the Hi-tech seed production system.

##### ***4.2.1. Conventional system***

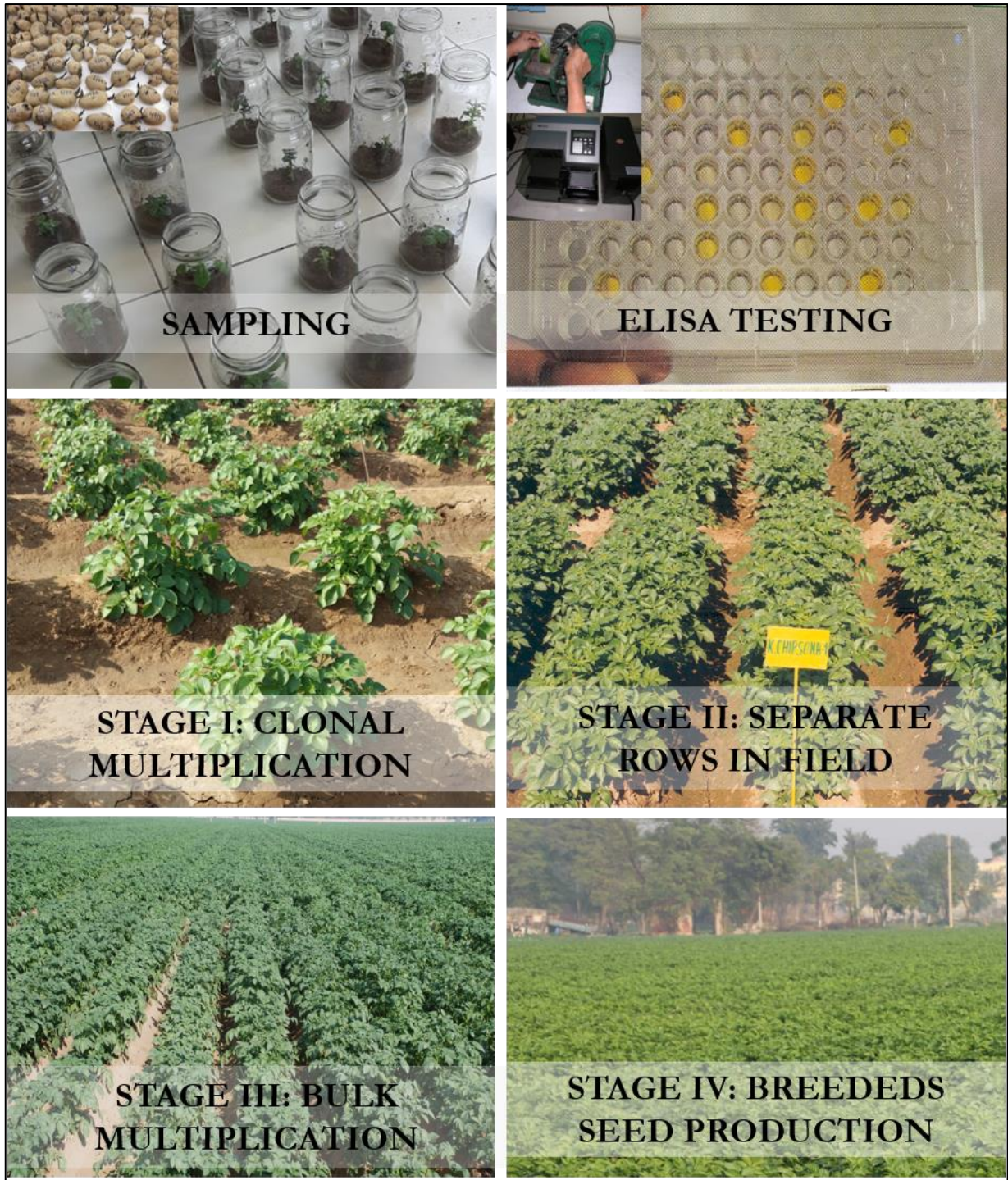
The conventional seed production system involves the testing of the initial tuber planting material for freedom from major viruses which is referred to as the indexing of tubers and involves the sampling of elite tubers and development of plants from scaped eyes, which are then tested using ELISA (Enzyme-linked immunosorbent assay) for the major prevalent viruses. Presently in India indexed tubers are mainly tested for viruses PVX, PVY (strains PVYo, PVYn and PVYc), PVA,

PVM, PVS, PLRV and for viruses PSTvd and PLCV through PCR. The selected tubers free from viruses are subsequently multiplied in 4 consecutive stages I to IV (Fig. 5). In this system the stages up to the production of breeder seed is handled by the concerned institution which is the producer of the variety (CPRI and its regional stations). All the stages are then grown and monitored according to the seed testing parameters. The breeder seed developed undergoes three more multiplications in the form of foundation I, II and certified seed, which is generally taken up by the various government organizations, before its distribution to the farmers. The breeder seed and the advanced generations are duly inspected and passed for quality. However, the main drawback of the system is that the seed distributed to the farmers has already been provided several generations of field exposure, which may deteriorate its quality over time. The other major issue is with regard to the size and number of the tubers produced in the system which cannot be regulated on field using cultural practices. The Hi-tech system was formulated to overcome this issue, which is also operational in the state.

#### ***4.2.2. Hi tech seed production system***

The Hi-tech seed potato production technology evolved for overcoming the constraints of the conventional system. The methodology involves the use of meristem tip culture to raise the virus free microplants of the varieties. These are then multiplied 8-10 times to get microplants, which may be, introduced into seed production either through cultivation in net house, culturing as microtubers or through aeroponics technology. The Institute has been instrumental in providing the necessary training for tissue culture and the technology of aeroponics has been transferred to several private seed producers. The hi-tech seed production system has therefore gained much momentum in the state of Punjab, with several private companies establishing the tissue culture laboratories and aeroponic units. ICAR-Central Potato Research Institute, Shimla supplied 222, 263 and 144 microplants of potato varieties to various private companies and state horticulture departments during 2018-19, 2017-18 and 2018-19 respectively (Table 4).





**Figure 5 Conventional seed production system**

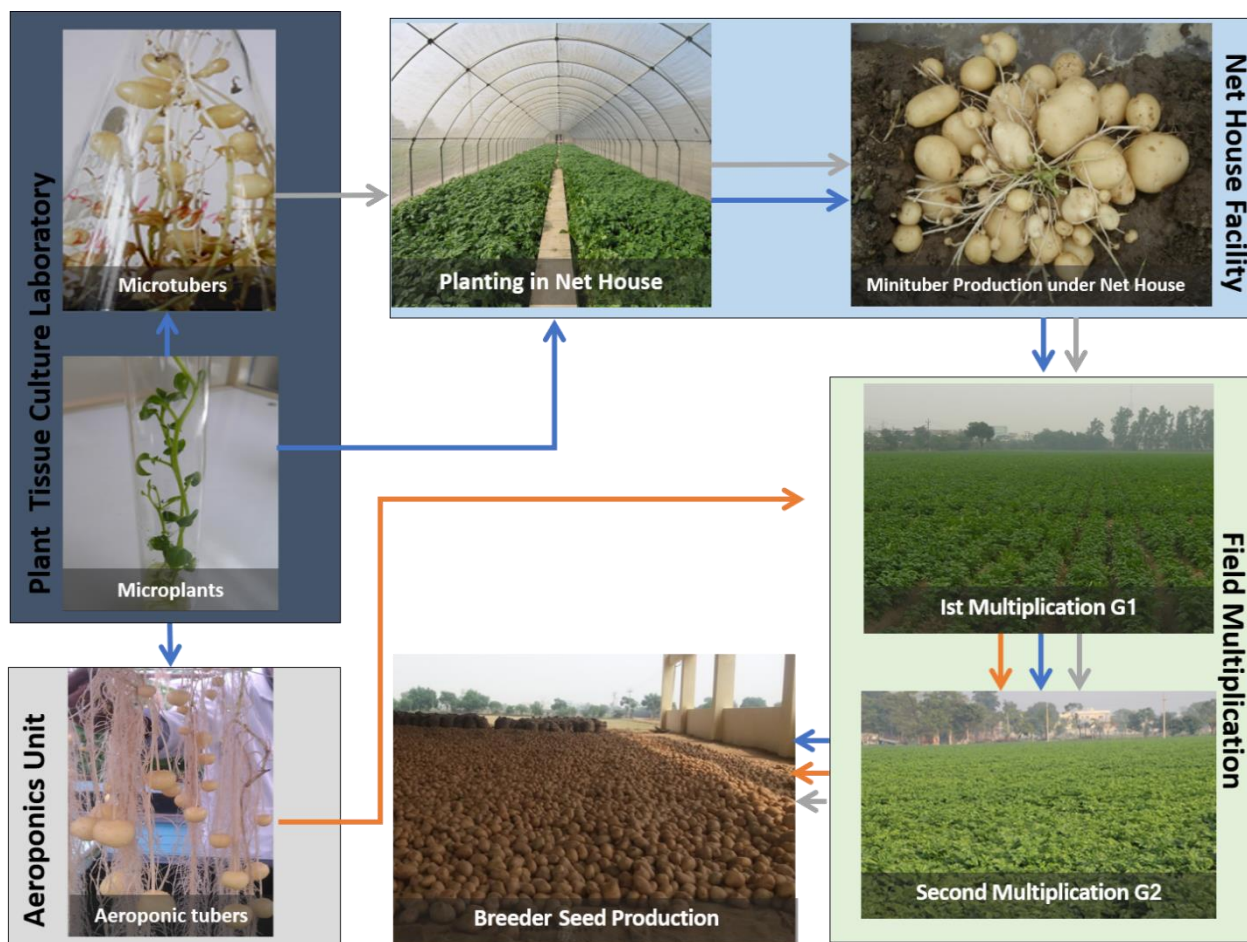
**Table 4: Supply of disease free microplants to various private and government organisations from ICAR- Central Potato Research Institute, Shimla during 2016 to 2019.**

Year	2018-19	2017-18	2016-17
<b>Total microplants supplied</b>	222	263	144
<b>Number of private firms</b>	14	27	23
<b>Government agencies</b>	4	3	2
<b>Number of varieties supplied</b>	19	14	15
<b>Private firms from Punjab</b>	3	7	6
<b>Punjab Government agencies</b>	1	1	0

Source: Annual Report 2016-17, 2017-18, 2018-19 of ICAR- Central Potato Research Institute, Shimla, HP

Currently 3 commercial tissue culture production units are recognized in Punjab by the Department of Biotechnology (DBT), Govt. of India. The adoption of hi-tech seed production technologies developed by the Institute has led to opening of more than 20 tissue culture labs throughout the country. Several private seed companies such as M/s Reliance Transgene Bioplants Pvt. Ltd., Chandigarh; Phulwari Bio-Tech Ltd., Chandigarh; Chamal Agritech Ltd., Chandigarh; TechnicoAgri Sciences Limited, Chandigarh; Sangha Seeds, Jalandhar; Mahindra Subhlabh Services Ltd., Mohali; Bhatti Tissue Tech, Jalandhar are taking virus free in-vitro plantlets from CPRI for further multiplication in their seed production programme. Two tissue culture laboratories Bhatti Tissue Tech., Jalandhar, Mahindra HZPC Pvt Ltd, Mohali and PepsiCO India Holding Pvt. Ltd., Hoshiarpur have gained recognition from DBT (Source: <http://dbtncstcp.nic.in/Punjab>). In lines of the same several aeroponic units have also been established, using CPRI developed aeroponics technology like Shekhon Biotech, Sandhu Biotech, Bhatti Biotech, Hargobind Seed, JPG Biotech Producers Pvt. Ltd. and also under the Punjab Horticulture department Dogri farm.





**Figure 6: Hi-tech seed production technologies**

### 5. Varieties cultivated for seed and consumption

About 66 potato varieties have been indigenously developed and released in India over the period of time. Out of these, only 45 varieties were found to be cultivated in India in 2015 (Pradel *et al.* 2015). Besides these foreign varieties namely Lady Rosetta, Atlantic, and Desiree are being grown in the states of West Bengal and Gujarat have been introduced to the country and adopted. Foreign released varieties like Cardinal, Diamant, Kennebec, Innovator, Santana, Shepody, *etc.*, are only grown in small pockets in Uttar Pradesh, Gujarat, and West Bengal, are used mostly for processing. An evaluation of the varietal preference in the state of Punjab has revealed that more than 80% of the area is planted with early-maturing varieties, more precisely, Kufri Pukhraj which suitably fit in the intensive rice- wheat cropping system of Punjab. The variety occupies 64% area, amounting to 57,411 ha, followed by Kufri Jyoti in 14,625 ha (16 %) and Lady Rosetta in 3600 ha

(4%). The other varieties like Kufri Badshah, Kufri Chandramukhi, Kufri Ashoka, Kufri Khyati and Kufri Surya, Kufri Jawahar, Kufri Ashoka and Kufri Lauvkar are popular and have been well adopted are also cultivated in the rest of the area (Pradel et al. 2015, [https://pau.edu/potato/Potato\\_cult.php](https://pau.edu/potato/Potato_cult.php)). The processing varieties both for seed as well as consumption have carved a niche of their own with varieties like K. Chipsona 1, K. Chipsona 3 and Kufri Frysona being cultivated in recent years. The farmers associations and private companies also produce truthfully labeled seed of some exotic varieties like Lady Rosetta, Spunta, Atlantic (ATL), Krudda, Santana, Hermes, Diamant, and Cardinal. Certain indigenous varieties developed under the informal system like B6, S1, Super 6 are also popular in the region.

Besides, some varieties grown mostly under contractual farming have been registered by the private companies like PepsiCo India Holding Pvt. Ltd. for varieties like FL1867 and FL2027. HZPC Holland B.V. for varieties HZD01-58, Panamera, Kastelli, Memphis, Evora, Sagitta, Taurus and Crisps 4 (Protection of Plant Varieties and Farmers' Rights Authority, India, 2018). Processing varieties utilized by the processing industries are under strict contract farming having limited areas under cultivation.

#### ***6. Distribution and movement of potato seed from Punjab***

The seed produced in the state from both formal and informal seed system is transported to the neighboring states of Karnataka, West Bengal, Maharashtra in large quantities. Most of seed distributed to the farmers of these states is of the informal seed category referred to as the truthfully labelled seed. The seed produced in the state is either sold directly by the farmers through their outlets to the growers in the neighboring states or through established agencies like NHRDF, NSC, ITC, Pepsico etc. or through progressive big farmers having ample capacity to handle the marketing.

In India, the agricultural marketing system largely operates under the forces of demand and supply. Trade is mainly in the hands of private enterprise, with governmental intervention mainly

limited to protecting the interests of producers and consumers and to the promoting of the organized marketing of agricultural commodities (Report of Joint Inspection Team to Review of NHM and other Central Scheme of Horticulture for Punjab) The marketing channels prevalent in the state have been classified as follows (<http://agmarknet.gov.in/others/profile-potato.pdf>)

### **6.1. Private**

The different private agencies such as Producers, Commission agent, Wholesaler, Retailer and consumers are involved in the route of marketing channels of potato. These are

- Producer → Cold storage → Commission agent → Wholesaler → Retailer → Consumer
- Producer → Commission agent → Wholesaler → Retailer → Consumer
- Producer → Wholesaler → Retailer → Consumer

### **6.2. Institutional:**

Due to price fluctuations and glut situation in the market, some institutions like National Agricultural Co-operative marketing Federation (NAFED), different state govt. agencies, co-operative societies are intervening in the domestic market and Agricultural and Processed Food Export Development Authority (APEDA) for export purpose to stabilize the prices. The major institutions having presence in Punjab and involved in potato marketing have been tabulated in table 5.

Marketing fluctuation has a huge effect on the overall potato production and also on the potato seed production *per se*. This also depends on the arrival of the commodity, at the time of harvesting in the market and its off-season status.

## **7. Punjab as the Agri-export Zone (AEZ) for potato:**

The policy for setting up of Agri-Export Zones was announced by the Ministry of Commerce, Government of India on the 31st March, 2001 with the primary objective of boosting agri-exports from the country. The Agricultural and Processed Food Export Development Authority (APEDA) under Ministry of Commerce, Govt. of India was appointed as the nodal agency to promote the

setting up of such zones. In this Punjab along with Uttar Pradesh, West Bengal and Madhya Pradesh were identified as Agri-export Zone (AEZ) for potato.

**Table 5: Major government and Semi-government organizations providing the services on marketing information and extension**

Agency	Role and functions
Directorate of Marketing and Inspection (DMI), CGO Complex, Faridabad, www, agmarknet.nic.in	It is at present implementing a plan scheme i.e. Market research and information network (MRIN) through NIC for establishing a network for speedy collection and dissemination of market information for its effective utilization. Under the scheme, important agricultural markets, state agricultural marketing boards/ departments are being linked through computerized internet services. A website namely AGMARKNET provides the updated relevant information. It also carries our marketing extension
Directorate of Economics and Statistics, Ministry of Agriculture, Shastri Bhawan, New Delhi, Website: www. Agricoop.nic.in	Compilation of agricultural data on agricultural commodities for planning and development. Dissemination of data/ information on agriculture through publication and internet
National Horticulture board, Plot No. 85, sector 18, Institutional Area, Gurgaon-122015	Collection, compilation and dissemination of market intelligence, market related information/ data on horticultural commodities including potato
Central Potato Research Institute (CPRI), Shimla, Himachal Pradesh, website: www.cpri.ernet.in	Acting as a center for training methodologies and technology for upgrading scientific manpower in modern technologies for post-harvest management of potato. Provides consultancy
Agricultural Produce market committees (APMCs)	Providing market information on arrivals, prevailing prices in different markets through display boards and public address systems Providing information on other markets Organizing trainings, tours, exhibitions on for farmers and beneficiaries
State agricultural marketing Department/ Directorate	Provides agricultural marketing related information Arranging publicity programme through demonstration, farmers' meetings etc. Dissemination of information through literature, radio and TV programme
State Agricultural Marketing Boards	Provide market related information by coordinating all market commodities in the state arranging training facilities to farmers and other beneficiaries Organizing seminars, workshops and exhibitions on agricultural marketing
Akashvani Kendras of New Delhi/ State capitals/ other cities	Broadcast programmes to disseminate the market information on agriculture
Doordarshan Kendras of New Delhi/ State capitals/ other cities	Telecast programmes to disseminate marketing information on agriculture

The total potato export during 2016-17 was 4,09,026.84 MT and in 2017-18 was 4,18,067.64 and in 2018-19 was 3,93,507.04 having a value of Rs 74,841.55, 56,079.42 and Rs 60,127.64 lakh rupees respectively (APEDA) (Table 6). In insight into the export of potato from Punjab reveals that in the last four financial years there has been no export of ware potatoes from Punjab whereas during 2018-19 and 2019-20 889 and 196.8 q of seed tubers were exported (Table 7).

**Table 6: Export of potato in different forms from India to the other countries**

	2016-17		2017-18		2018-19	
	Qty (t)	Rs. Lacs	Qty (t)	Rs. Lacs	Qty (t)	Rs. Lacs
<b>Potatoes Other Than Seed, Fresh/Chilled</b>	3,96,340.67	66,147.51	3,95,748.12	41,182.50	3,67,390.99	44,078.00
<b>Potato Seeds, Fresh/Chilled</b>	1,146.78	707.65	4,174.72	1,331.94	1,671.35	656.82
<b>Potatoes Dried</b>	3,263.08	842.38	368.44	159.27	1,959.37	232.87
<b>Potato Starch</b>	437.03	305.68	1,041.54	420.44	135.95	103.27
<b>Potatoes, Uncooked/Cooked by Steaming/Boiling in Water, Frozen</b>	1,025.86	561.06	1,117.03	314.16	3,679.73	639.36
<b>Potatoes, Prepared/Preserved Otherwise Than by Vinegar/Acetic Acid, Frozen</b>	6,813.42	6,277.27	15,617.79	12,671.11	18,669.65	14,417.32
<b>Total</b>	4,09,026.84	74,841.55	4,18,067.64	56,079.42	3,93,507.04	60,127.64

(Source APEDA)

**Table 7: Export of potato from Punjab as seed and ware**

		2016-17		2017-18		2018-19		2019-20 (April-December)	
		Qty (t)	Rs (Lakhs)	Qty (t)	Rs (Lakhs)	Qty (t)	Rs (Lakhs)	Qty (t)	Rs (Lakhs)
<b>Export of seed potatoes</b>	Punjab	0	0	0	0	889	235.43	196.8	55.66
	Total	1122.28	707.65	4055.1	47.31	889	297.33	196.8	401.01
<b>Export of ware potatoes</b>	Punjab	0	0	0	0	0	0	0	0
	Total	159879.7	61856.78	143814.3	36302.87	144292.9	40748.16	111690.7	42425.04

(Source: APEDA)

The real potential of export from Punjab is still unexplored and with seed potato fetching highly remunerative prices as compared to ware potato, there is much scope for the state of Punjab to

harness the opportunity and increase the profitability of the potato seed growers. This is a clear indicative of the profitability of seed export that can be harnessed by the farmers of the region, under the government designated rules and regulations.

Punjab Agro Industries Corporation Ltd. (PAIC) along with subsidiary Corporations viz. Punjab Agri Export Corporation (PAGREXCO) and Punjab Agro Food grains Corporation (PAFC) plays a vital role in establishing Food Parks, Processing Units for fruits & vegetables, organic cultivation of crops & its export and procurement of food grains in the state. MARKFED (The Punjab state cooperative supply and Marketing Federation Ltd.) has been declared as the is as nodal agency by Agricultural and Processed Food Products Export Development Authority (APEDA) (through the Ministry of Commerce and Industry) for setting up the Agri export zones (AEZ)/ Agri export from Punjab. The project that coordinates the efforts of various organizations like National Horticulture Board (NHB), NFPI, APEDA, ICAR, MOA, Revenue department and the various State Government agencies like the Department of Agriculture and Industries and acts as the main link between Central and State agencies and the stake holders who are farmers, exporters and processors. It has designated responsibility to study of Quarantine Pests and other problems in Potato, organising global GAP (good agriculture practices) certification, organising integrated nutrient management/integrated pest management studies, organising farmer training camp for rectification of problems faced by farmers for potato cultivation and suggest methods for improvement in yield of Potato for promoting its export. The intention of these authorities is to link any future potato export to the EU with the GAP (Good agricultural Practices) certification scheme. A lot of stress is also on the geo tagging of the potato produced in Punjab. As no potato exports are allowed to the EU, there are few farmers participating in the GAP certification scheme so far. MARKFED has registered 242 potato producers and has enabled them to obtain GAP certification, ensuring quality production and traceability and provided them with a GAP certification code number. DPPQS (Directorate of Plant Protection and Quarantine and storage)



has mandated a list of officers of Plant Quarantine Stations across the country and other central/State government agencies as eligible to carry out pre-export inspections and issue phytosanitary certificates. Farmers interested in exporting potatoes are required to be registered with MARKFED for tracing back purposes and to meet the export standards applied under GAP certification scheme. Each consignment for export has to be accompanied by a sales invoice issued by the suppliers along with appropriate labelling and transport documents from the place of production to the point of export. Mixed consignments bear tags with producers' specific ID codes. Seed potato export from India is mainly destined to Sri Lanka and Middle East while ware potatoes are exported mainly to Pakistan and Nepal.

#### **8. *Potato production in Punjab under the changing climate conditions***

Other simulations are less severe, projecting a yield reduction of 'only' 2.5–13.72% between 2020 and 2050 (Singh and Lal, 2009; Kumar *et al.*, 2015). On the other hand, in the north-western parts of the country, yield gains are expected as temperatures move towards optimal levels from current low temperatures (Singh and Lal, 2009). Punjab has, in relation to other states, the most balanced resilience. High drought tolerance, late blight resistance, and early maturity are found in adopted varieties. Despite the Heat Tolerance Index (HTI) being very low, the state is predicted to become warmer, which will favor potato production. Heat tolerance is thus of less importance. Similarly, due to expected increases in (extreme) rainfall, droughts are unlikely to become an issue for potato production. Given the already high Drought Tolerance Index (DTI) for Punjab (0.84), attention can be redirected to other more important traits in the Punjab context. Late blight will remain an issue given hotter and wetter weather predictions and a current late blight index (LBI) of 0.57 (Pradela *et al.*, 2019). Increases in atmospheric CO<sub>2</sub> concentration levels may compensate for increases in temperatures, resulting in overall stable potato yields in Punjab (Dua *et al.*, 2013). Punjab has been established as a seed potato production area on the basis of its unique climatic conditions, which ensures low vector population for efficient potato seed production system. The

looming climate change and its effect on the changing vector dynamics poses a major threat to the seed production sector in the state. It has been stipulated to have profound effect on potato growth story, impacting every aspect of not only production and profitability, but also seed multiplication, storage, marketing and processing of this perishable vegetatively propagated crop (Singh *et al.*, 2008). Temperatures are projected to rise by 0.5 °C by 2030, resulting in fewer rainy days and more extreme weather events, such as prolonged droughts (NIC, 2009). If left unaddressed, climate change and variability may undermine rural incomes and food security in India by longer spells of water shortages and increased incidence of pest and diseases (Singh *et al.*, 2013). Dua *et al.* (2013) carried out a simulation study of climate change for combined effects of increased temperature and CO<sub>2</sub> fertilization on overall potato production in Punjab. It was simulated that under the unaltered future acreage, the overall productivity of 3 potato varieties considered in the study Kufri Badshah, Kufri Jyoti and Kufri Pukhraj will increase by 3.3%, 3.1% and 3.6% in 2020, although the potential productivity will again decline to base line yield values in 2055 (+0.1%, -1.5% and -1.9% respectively). The increased temperatures would force early maturity, as thermal time for each stage would be achieved early. Data analyzed by the India Meteorological Department indicates that for projected climate change for Punjab in 2021-2050s with respect to 1961-1990, potato yield is likely to increase by 7.2% by 2030s (2021-2050) if temperature increases up to 1°C and CO<sub>2</sub> concentration is maintained at 440 ppm. There is projected increase in average precipitation by 13-22%, Annual maximum and temperature to increase by 1.0-1.8°C and 1.9 to 2.1°C respectively. Drought days in Kharif with precipitation less than 10mm to extend by 23-46 days within the lower Sutlej basin lying within Punjab.

The seed plot technique was the sole premise for Punjab to have evolved as disease free seed producer of the country. In the face of climate change, there would be expected changes in the virus vector populations in the region. The population of potato peach aphid (*Myzus persicae*) has been reported to advance by two weeks for every 1°C rise in mean temperatures and population

build up is positively correlated maximum temperature and minimum relative humidity (Biswas *et al.* 2004, Dias *et al.* 1980). The increase in temperatures under global warming would most certainly affect the earlier appearance and increase in population of the aphids, imposing a major constraint on the disease-free period available for seed production, especially in Punjab. The evolution of the Hi-tech seed production might provide some respite under the changing climate conditions, whereas new areas need to be established for seed production.

### 9. Cold store facilities in the state

The total estimated monthly consumption of potato (from NSSO data) equals 3881674 metric tonnes. The corresponding figures of production and demand have been depicted in table 8. It is estimated that demand during January to April is met from fresh harvest and the remaining 8 months of demand is met through inventory held at cold stores.. Therefore, with 15.5 million metric tons being consumed from fresh stock within first 4 months of harvest (Jan-April), the remaining quantity of 29.5 million metric tons (Approx. 75% of total considered production of 39.78 million metric tons), is dependent on term bulk cold stores. Therefore, cold store not only caters to continued trade of the commodity during the lean period but more importantly for securing the planting material for the next planting season.

**Table 8: Household consumption of potato in India 2011-12 Annual demand includes Personal consumption, bulk consumption in hotels, marriages etc, Exports, seeds, losses, processing etc**

Year	Production (000" t)	Annual demand (000"t)	Surplus/ deficient (000"t)
2012-13	45344	42203	3141
2013-14	41555	41502	53
2014-15	42174	42151	23
2015-16	43417	43169	248
2016-17	48237	45739	2498

Source: NSS Report No. 558

Based on the estimates by the All-India Cold Storage Capacity and Technology - Base line Survey (10.12.2014) conducted by M/s Hansa Research Group, commissioned by National Horticulture Board (NHB) under Department of Agriculture, Cooperation & Farmers Welfare out of the total 3874 (17555768 MT) cold stores used for storing horticulture products, 2690 (14539420 MT) cold, about 83% storage capacity is occupied by single commodity potato.

However, the most recent statistics as reported by Ministry of Food processing Industry to the Press Information Bureau in 2017, Punjab has 660 cold stores with a cold store capacity of 2155704 (National horticulture Mission, National Horticulture Board and Ministry of Food Processing Industries and survey conducted). These are mainly under the National horticulture Mission, National Horticulture Board and Ministry of Food Processing Industries. The state stands 4<sup>th</sup> in cold storage capacity for the overall position in the country after Uttar Pradesh, West Bengal and Gujrat.

The cold store facility is most critical support for the potato seed production as well as ware potato production. In the absence of a cold storage and related cold chain facilities, the farmers are forced to sell their produce immediately after harvest which results in low price realization and potato gluts. The table purpose tubers are stored at 7°C and 98% RH, to minimize reducing sugar formation, which otherwise produces a sweet off flavor to tubers. Similarly, processing industries require cold store of potato tubers at specific conditions to limit formation of reducing sugars, which deteriorate processed product quality. Tubers of processing grade are stored at 8-12°C and 95% RH. Simultaneously, they are used to store potato seed stocks upto the onset of the next *Rabi* season requiring storage of tubers at 2-4°C and 95% RH. The storage requirement for table, processing and seed potato is different. Potato is indeed the major important food commodity cold stored in India (Alur and Maheshwar, 2017). The district wise distribution of the cold stores in Punjab follows the similar patterns as of potato production in the districts.

## ***10. Issues related to potato seed production in Punjab***

There are several issues related to the production of seed potato. The cultivation issues of both seed and ware potato are the same, however seed production is a much more technical and, sophisticated and labor intensive, consecutively fetching higher remunerations. The major issues identified related to Potato in the state of Punjab have been summarized.

Achieving optimal seed replacement rates is the focus area for ensuring efficient mechanisms for quality seed supply and appropriate seed varieties taking into account the native agro-ecosystems and the pest profile of the region (Planning Commission, 2011a). The desirable seed replacement rate (SRR) of 25% has been reported to be optimum to get good production and productivity of potato in the country (Singh and Pandey, 2013). The potato production was 2164000 ha in 2016-17 which requires a seed quantity of 135.250 MT to achieve the 25% replacement target at 2.5 t/ha seed rate.

The impact of climate change needs to be accessed thoroughly, in relation to vector dynamics and shortening of growing window. There is a requirement of being vigilant to emerging new vectors (white fly, thrips, *A. gossypi* (aphids), hoppers, Psyllids), virus diseases, new viral diseases like PALCV, CMV, PAMV, PVYn, soil and tuber borne diseases (common scab, russet scab, black scurf, brown rot, Sclerotium wilt, Sclerotinia stem rot, Verticillium wilt and nematodes). There is a dire need to avoid monoculture of potato and implementation of stringent quarantine norms in movement of plant materials within the country. Non availability of disease resistant varieties has been reported as a major constraint in potato production in a study by Arneja et al. (2009).

The bulky and perishable nature of the potato seed requires careful handling optimum temperatures, to retain its quality. A proper cold store regulatory authority to improve the cold store facilities in the state as well as for fixing of charges for cold store annually is required.

The crop is extremely sensitive to fluctuating productions as well as prices in the market, which also affects its seed production. The production risk arises mainly due to the adverse climate and limited access to resources leading to uncertain connections to markets and poorly connected

value chains. The marketing cost is high with the existence of large number of marginal farmers. These can be improved by providing reliable advisory and information systems to the farmers and promoting producer's co-operative in potato growing areas to reduce the price gap between growers and consumers. The information systems can provide advance forecasting of area under potato for ample seed production and efficient and cost-effective utilization. The formulation of a meticulously researched seed rolling plan based on suitable projections will provide a strong direction to potato seed production in Punjab and improve seed replacement rates.

A strengthening of Indian Potato Export Policy including measures to improve infrastructure for movement of potatoes from producing areas to exporting countries are required for further promoting export of seed and ware potato.

Seed certification agencies need to be strengthened to ensure proper seed multiplication, monitoring and distribution. There is an increased trend of certification for quality improvement of seed in Punjab. However, rate fixation of certified and uncertified seed potato is an issue as these are almost at par. Approximately 11960 tones seed potato was certified during year 2017-2018 in Punjab state. Traceability of seed has also gained momentum in recent year, to assure the farmers of Punjab to fetch good prices for the seed produced

## ***11. Conclusion***

The state is an identified pest free area status and has emerged and established itself as the major potato seed producer on the map of India. However, in face of the emerging competition and changing vector dynamics in the face of climate change there is a strong need to focus on specialized skill intensification with relation to seed production techniques especially hi-tech seed production methods. There is also much scope for strengthening of technology/ knowledge dissemination, model deployment like farmers' participatory approach and seed village programmes. In a state like Punjab where private seed producers have played a key role in bringing a nationwide potato seed sustainability through the prevalent and much popular informal seed system, these are essential to ensure the quality of the seed and seed stocks used.



The seed is the basic input for potato farming therefore the integrated seed health strategy with more focus on on-farm management and host resistance along with strengthening of formal seed systems as proposed by Sharma *et al.*, 2015 may also serve as a long-term strategy in ensuring quality seed supply to the growers. It is also proposed that the informal seed may be certified to the extent that it is on the basis of its marked quality, which may not necessarily be kept at the disease-free threshold, as is the case with formal seed system. This will improve transparency and promote sale of good quality seed.

The coexistence of the public and private players has added diversity and effectiveness in meeting to the potato seed requirement in the country making it more economical and drastically improving the seed replacement rates of marginal farmers. This has been one of the major factors contributing the brown revolution, witnessed in India. Public Private Partnership (PPP) approach and MOU's may be sought for increased seed marketing.

Development and implementation of relevant government policies allowing ease of export for disease free seed can bring more vigor in the potato seed industry of Punjab. It offers much opportunity for increasing the profitability of the growers, improving the overall economy of Punjab and generating employment. Seed testing and quality assurance is one area where lots of policy, infrastructure and human resource support is needed. This also requires establishing world class facilities for seed testing, certification and to match requisites of international conventions viz., UPOV, ISTA etc., so that seed from India can carve its niche in international trade.

In view of the seed production technology there is a large scope for adoption of the hi-tech seed production systems which ensure mass production of high quality, disease –free seed. These technologies are more resilient to climate change, in time promise reduction in seed production costs thereby making seed more affordable to the potato growers everywhere.

Further, there is a dire need to be vigilant of the climate change trends, although it is simulated to increase the potato production over the baseline levels by 2050, but the changes in

vector dynamics and emergence of new diseases and viruses may pose a major threat to the current potato seed production areas of the state. The potato seed industry in Punjab should be proactive in exploring the future seed production methodologies and implementing the necessary quarantine policies to retain its vector-free status. These will in turn promote exports from the state.

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