Nepal Agriculture Research Journal
Vol.15, No 1, pp. 1-19, 2023
DOI: https://doi.org/10.3126/narj.v15i1.51015

Does potato seed system working effectively in Nepal?

Samaya Gairhe[1*], Krishna Prasad Timsina[2], Yuga Nath Ghimire[1], Surya Prasad Adhikari[2], Devendra Gauchan[3], Kalika Prasad Upadhyay[4], Benu Prasad Prasai[5] and Prakash Bhattarai[6]

[1]Nepal Agricultural Research Council, Nepal
[2]National Agricultural Policy Research Centre, Khumaltar, Lalitpur, Nepal
[3]Alliance of Bioversity International and International Centre for Tropical Agriculture, Kathmandu, Nepal
[4]Directorate of Agricultural Research, Gandaki Province, Nepal
[5]Seed Quality Control Centre, Hariharbhawan, Lalitpur, Nepal
[6]National Potato Research Program, Khumaltar, Lalitpur, Nepal
*Corresponding author's email: samaya43@gmail.com
*ORCID: https://orcid.org/0000-0002-1735-3334

ARTICLE INFO

Research Paper

Received: September 25, 2022
Revised: December 02, 2022
Accepted: January 10, 2023
Published: February 01, 2023

Contents available at http://www/sasnepal.org.np

ABSTRACT

The present study analyses the gaps and issues in the production and distribution system of potato seeds in Nepal. Households' survey combined with focus group discussions (FGDs) and key informant interviews (KII) were carried out to collect the information. Gross benefit and descriptive statistics were employed for the analysis of the data. Results revealed that National Potato Research Program (NPRP) and some private companies were responsible for the zero generation Pre-Basic Seeds (PBS) production. National Centre for Potato, Vegetables and Spice Crops Development Program (NCPVSCDP) collects the seed demand and helps in potato seed certification at the farmers' level. The current production is inadequate to meet the demand. As the present potato productivity is 16.72 mt ha^{-1} which is less than projected by National Seed Vision (NSV), reducing the yield gap is one of the important ways to meet the demand. The Gross benefit per hectare of first-generation basic potato seed (BS1) was NRs 14, 66,667 ($ 12,759) and second-generation basic potato seed (BS2) was NRs 9, 20, 667 ($ 8,009). However, the potato seed system is not working effectively in Nepal. Therefore, the adoption of improved potato varieties should be extensive through a strong mechanism for maintaining the full seed cycle and its proper distribution. Further, it is equally important to change the perception of farmers by showing the comparative benefit of growing ware potato and seed potato.

Keywords: Potato, PBS, basic seed, seed system, varieties

Cited as: Gairhe S, K Timsina, YN Ghimire, SP Adhikari, D Gauchan, KP Upadhyay, BP Prasai and P Bhattarai. 2023. Does potato seed system working effectively in Nepal?. Nepal Agriculture Research Journal 15(1): 1-19. DOI: https://doi.org/10.3126/narj.v15i1.51015

INTRODUCTION

Seed is an important input to increase agricultural productivity and ensure the food security of smallholder farmers. The seed system is crucial for timely supply at required time, quality seeds of diverse crops and varieties to farmers (Kansiime and Mastenbroek 2016). Ensuring farmers' access to quality seed can only be achieved through a viable, dynamic and holistic seed system that can source new diversity, multiply, market and promote use of quality seeds to small farmers timely and efficiently at affordable prices (Gauchan 2019). Conventionally, there are two seed systems; formal and informal, recognized in Nepal (NSV 2013). The informal seed system is characterized by production and preservation of seed potato by farmers for subsequent planting seasons. Whereas, the formal seed system is vertically organized by public and private organizations for production and distribution of tested and released/ registered varieties using standard quality control mechanisms (NSV 2013). In Nepal, only about 22% of the total demanded seed of different crops was supplied by a formal seed system (SQCC 2022), and seed supply through formal channels was not well established (Sulaiman and Andini 2013). Likewise, an earlier study by Ghimire (2005) stated that the majority of the farmers were using the informal source for potato seed, which resulted in the lower yield.

Seed Act 1998 (2nd amendment 2022), Seed Policy 1999, Seed Regulation 2013, and National Seed Vision 2013-2025 are the major seed legislations and policy frameworks that guide and regulate seed production and marketing in Nepal. These policies are responsible for ensured production, processing, availability and supply of quality seeds in Nepal as the parts to build innovative and sustainable seed system as described by Spielman and Kennedy (2016). However, Timsina et al (2015) have reported weak and incomplete seed system that have been affecting the supply of seeds abundance in Nepal. True Potatoes Seed and Seed Potatoes are the two seed production system practiced in potato. True potato seeds, or "botanical potato seed" differentiate from "seed potatoes", which are genetically identical clones produced in large numbers by planting pieces of a potato stem or tuber or through tissue culture. True Potatoes Seeds production system is less popular as compared to Seed Potatoes (NCPVSCD 2019). In Nepal, two seed quality assurance system have been commonly practiced that includes formal certification system and truthful labeling system (self-quality declared system). Since seed certification is complex and must meet obligations in terms of infrastructure and human resources, therefore, truthful labeling system is more common now in Nepal. According to SQCC (2017), the seed generations cycle adopted in potato for certification system categorized as Pre-Basic Seeds (Breeder's seeds), Basic Seeds 1 (Foundations Seeds), Basic Seeds 2 (Certified Seed 1), Basic Seed 3 (Certified Seed 2) and Improved Seed (Subsequent 2-3 generations). Whereas, in truthful labeling system, the generation of seed potatoes are categorized as Breeder seed, Source seed, Label seed I, Label Seed II and Improved Seed (SQCC 2017).

In Nepal, Potato is one of the major staple food crops being cultivated in 198,788 ha with production of 3,325,231 mt and productivity of 16.72 mt ha^{-1} (MoALD 2022). Province one is the largest province in terms of potato area (31%) and production (30%) followed by Bagmati province which constitutes the 21% and 23% of total area and production, respectively (NCPVSCD 2019). Potato constitutes one of the major sources of income for smallholder farmers in high mountain regions of Nepal (Khatri et al 2004; NPRP 2014; Timsina et al 2011). Seed potatoes grown in higher elevations in mountains are a major traditional and reliable source

of seeds for farmers in lower hills and lowlands because of their disease-free status in higher altitudes (Rhoades 1985) as the disease infestation leads to low productivity (Bajracharya and Sapkota 2017). Potato is also an important vegetable crop produced in kitchen gardens; and also a cash crop for the farmers in the market accessible part of lower hills and Tarai (lowland). Considering its importance in the country, Nepalese farmers have been cultivating potatoes for over 200 years with the earliest record of its introduction in Nepal in 1793 (Rhoades 1982). However, this crop became economically important only in the 19th century (Rhoades 1985).

National Potato Research Program (NPRP) is an institution under Nepal Agricultural Research Council (NARC) of the Government of Nepal and has a mandate for generating technologies on potato such as varietal development, pre-basic seed (PBS) as well as basic seed production. NPRP has been producing PBS and basic seeds for three decades. These PBS and basic seeds are multiplied for as improved seed and then reached potato growers. The National Potato Development Program (NPDP); now conjugated to the National Center for Potato, Vegetables, and Spice Crop Development (NCPVSCD) of the government plays a pivotal role in the dissemination of potato-related technologies in Nepal. Presently, it has been working as the nexus between technology generators and end-users. Furthermore, it is involved in potato seed quality maintenance and provides subsidies to the farmers. Besides NPRP, private sectors mainly private tissue culture laboratories have been involving in seed potatoes production in different parts of Nepal. To date, eight private tissue culture laboratories have been involved in PBS production with estimated maximum capacity of 1.6 million PBS per year. However, the present production is around one million. Despite the increased involvement of private sectors, there are some issues regarding the seed potatoes certification mainly mother culture certification, ELISA testing and lab protocol and standard to be adopted by private sector. Due to which certification of PBS produced by private sector is still lacking. Recently, demand for potato seed is increasing rapidly in the country with the increased demand of potato as a vegetable in the diet. Hence it is becoming a cash crop that can be cultivated in short day condition during winter in Tarai and spring seasons in lower hills, though conventionally it was mainly a summer crop grown in the high-altitude region of Nepal.

Despite the production of large amounts of PBS annually, inadequate availability of quality seeds emerges as a major issue at the farm level every year. Therefore, this study was conducted to analyze the gaps and issues in the production and distribution system and suggest possible options to strengthen the existing potato seed system in Nepal by posing the following research questions:

- What is the status of adoption of NARC developed potato varieties in the farmers' field?
- Are different seed actors working effectively in coordinated approach to maintain the potato seed cycle?
- Is supply of potato source seed consistent with the national seed policy?

MATERIALS AND METHODS

Data collection and sources

We collected both primary as well as secondary data to find out the research questions posed above. Secondary data were collected from official publications and unpublished sources of Nepal Agricultural Research Council and the Ministry of Agriculture and Livestock Development, Nepal. For understanding the formal and informal sources of potato seed,

household survey of 508 households was carried out in 2018 from five major potato growing districts representing key agro-ecological zones such as Tarai, Hills and High hill (Mountain). The districts included from Tarai were; Jhapa, Bara and Kailali; for the Hill it was represented by Kavrepalanchok and for High hill it was Solukhumbu. Prior consent for interview was obtained from all respondents. The detail of sampling is presented in Figure 1 and Table 1.

Table 1. Agro-ecological zones of sampling areas and sample size

SN	Agro-ecology	Districts	Sample size
1	Tarai	Jhapa	102
2	Tarai	Bara	98
3	Tarai	Kailali	102
4	Hill	Kavrepalanchok	106
5	High Hill	Solukhumbu	100
Total			508

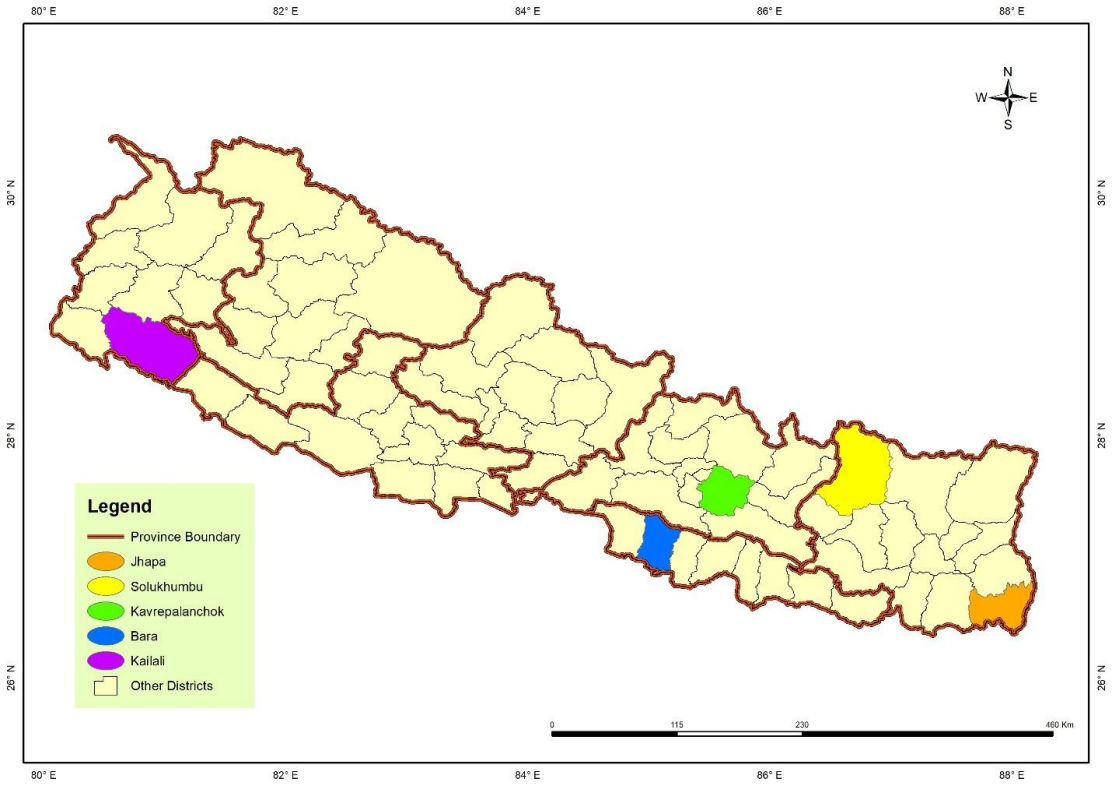

Figure 1. Map showing sampling districts

In addition to household survey data; Focus Group Discussion (FGD) and Key Informant Interviews (KII) were carried out to supplement and validate the information. FGD was conducted in the Panauti-3 municipality of Kavrepalanchok district with the farmer group "*Khadyanna tatha Biu Aalu Utpadak Samuha*" established in 2010 with 20 members. KII was conducted with the potato experts from the National Potato Research Program (NPRP), Khumaltar, and officials from the National Potato Development Program (NPDP) Khumaltar. Similarly, secondary information was collected from NPRP, NPDP, SQCC and Planning, Monitoring and Evaluation Division of Nepal Agricultural Research Council (NARC).

Data on released and registered potato varieties, target and achievement of Basic and PBS production of NARC, flow and distribution of PBS, basic seed, cost of production, sources of seeds for cultivating seed and ware potato, export, import of potato seed, seed vision target on potato were collected through both primary and secondary sources.

Analytical methods

Gross benefit and descriptive statistics were employed for analysis of the data and they are presented in both tabular and graphic forms. Estimated benefits were calculated using gross benefit analysis. The formula for estimating gross benefit, cost and return is outlined below

Gross Benefit = Gross Return-Total Variable cost

Where,

Gross return = Price of seed potato × Total seed potato production

Total variable cost = Summation of all variable costs

Variable costs = Cost of tuber, compost and chemical fertilizer, pesticides, irrigation, human labor and machine rent for land preparation, planting, intercultural operation, and harvesting.

RESULTS

Released and registered potato varieties in Nepal

The released and registered potato varieties in Nepal are shown in Table 2. The government of Nepal until 2020 has released and registered a total of 16 potato varieties recommended for cultivation in different agro-ecological regions of Nepal. Out of this, eleven varieties were released ones, and five were registered.

Table 2. Released and registered potato varieties in Nepal (1992-2020)

SN	Varieties Name	Year	Yield potential (t/ha)	Maturity days	Released or Registered	Recommended domain
1	Cardinal	2019	18-23	80-110	Registered	Tarai to Hill (100 to 4000 masl)
2	Rosita	2019	10-14	120-140	Registered	Central and Eastern High Hill (1600-3500 masl)
3	MS 42.3	2019	10-14	100-120	Registered	Tarai to Valleys of the hill (100-1600 masl)
4	Khumal Vikash	2018	25	100-120	Released	Mid and High Hill
5	Khumal Upahar	2014	24	100-120	Released	Tarai and Mid Hill
6	Khumal Ujjwal	2014	25	100-120	Released	Mid to High hills
7	TPS-1	2014	35-40	110-120	Registered	Irrigated area of Tarai and Mid Hill
8	TPS-2	2014	35-40	110-120	Registered	Irrigated area of Tarai and Mid Hill
9	Khumal Laxmi*	2008	28	100-140	Released	Tarai, Inner Tarai, Hill
10	IPY-8	2008	27	100-120	Released	Tarai and inner Tarai
11	Khumal Seto-1	1999	38.7	110	Released	Mid and High Hills
12	Khumal Rato-2	1999	36.2	95	Released	Tarai and Inner Tarai
13	Janak Dev	1999	39.4	110	Released	Tarai, Mid and High Hills
14	Desiree	1992	18.0	90-120	Released	High and Mid Hill, Tarai
15	Kufri Sindhuri	1992	23.0	110-120	Released	Tarai and Lower Hills
16	Kufri Jyoti	1992	23.0	110-120	Released	Mid and High Hill

***Commercial production has been restricted since 2017 due to its acridic taste after cooking*

Source: SQCC 2020

The yield potentials of released varieties' ranged from 18 mt ha^{-1} to 39.4 mt ha^{-1} and maturity days ranged from 90 to 140 days. These varieties were recommended for Tarai, Mid-hill and High hill based on their performances. Similarly, the yield potential of registered varieties ranged from 10-40 mt ha^{-1} with maturity days ranging from 80 to 120 days. However, the yield potentials of two registered True Potato Seed (TPS) varieties' ranged from 35 to 40 mt ha^{-1}which are recommended for all agro-ecological regions covering Tarai, Mid-hill and High hill.

Seed System Components

The seed system in potato includes different generation in seed cycles. The main components are PBS followed by basic seed/ source seed, certified/labeled seed and improved seed based on certification or truthful labelled system by quality control system adopted in Nepal.

PBS production from NARC

PBS in potato is equivalent to breeder seed used in major cereal crops. This is mainly produced and maintained by breeder/researcher in the research stations. Presently, NARC especially NPRP and certified private sector labs are the producer and maintainer of PBS of potato. Variety wise PBS production from 2015/16 to 2017/18 in NARC is presented in Table 3. On average NARC is producing about 200 thousand PBS in a year. However, the number has been declined in 2017/18, comparing to 2015/16 by about 30%. It is estimated that if the seed generation cycles for seed production are followed for multiplication, the PBS produced in 2015 by NARC could cover at least one-fourth of total potato cultivated area of Nepal. The annual demand for PBS was estimated at 1.5 million tubers per year while the production by NPRP was only 0.2 million tubers (MoALD 2020b). In 2019/2020, a total of 1,111,901 PBS was produced with involvement of private sector (SQCC 2022).

Table 3. Variety wise PBS production from 2015/16 to 2017/18 in NARC

S.N.	Potato Varieties	2017/18	2016/17	2015/16
1	Cardinal	43035	46276	43649
2	Khumal Ujjwal	30058	26034	22720
3	Desiree	18902	35135	35599
4	Janakdev	18812	45833	41180
5	Kufri Jyoti	14013	16982	17576
6	CIP 393073.179	10568	6034	0
7	Khumal Rato- 2	10248	7958	136
8	Khumal Seto-1	9572	31468	23858
9	IPY-8	9090	14182	22784
10	MS 42.3	8821	10001	7895
11	Khumal Upahar	8564	11233	427
12	Jumli Local	7358	3265	1777
13	CIP 395112.32	1526	10162	0
14	PRP 25861.1 (Khumal Vikash)	1297	2430	0
15	Kufri Sindhuri	1255	6606	4222
16	MF II	993	2197	604
17	TPS 1	580	2287	2256
18	Rosita	565	3415	1266
19	TPS 2	395	2136	1104
20	Khumal Laxmi	309	788	116
	Total	195,961	284,422	227,169

Source: National Potato Research Program, Khumaltar

In all three years, Cardinal variety of PBS was produced in the highest number. In 2017/18, Cardinal was produced the largest number followed by Khumal Ujjwal, Desiree, Janakdev, Kufri Jyoti, Khumal Rato-2, Khumal Seto-1, IPY 8, MS 42.3, Khumal Upahar, Jumli Local, Khumal Vikash, Kufri Sindhuri, TPS 1, Rosita, TPS 2 and Khumal Laxmi (Table 3) These PBS were multiplied as basic seeds and reached the farmers.

The target and achievement of PBS production from NARC are shown in Figure 2. Over 13 years (from 2006 to 2018), the range of target set was 150,000 in year 2006 to 327,110 in 2010 PBS, more than double as compared to 2006. Later after 2010 there is sharp decline of PBS production target to about 70,000 at 2011. The production target started to increase again from 2012 onwards and maintained the target of 150,000 up to 2014. Further the target was increased to 175,000 on 2015 and 2016. The PBS target was increased to 200,000 for the years 2017 and 2018. There is an inconsistent range of production target of PBS. Out of 13 years, NARC was able to achieve its target only for four years.

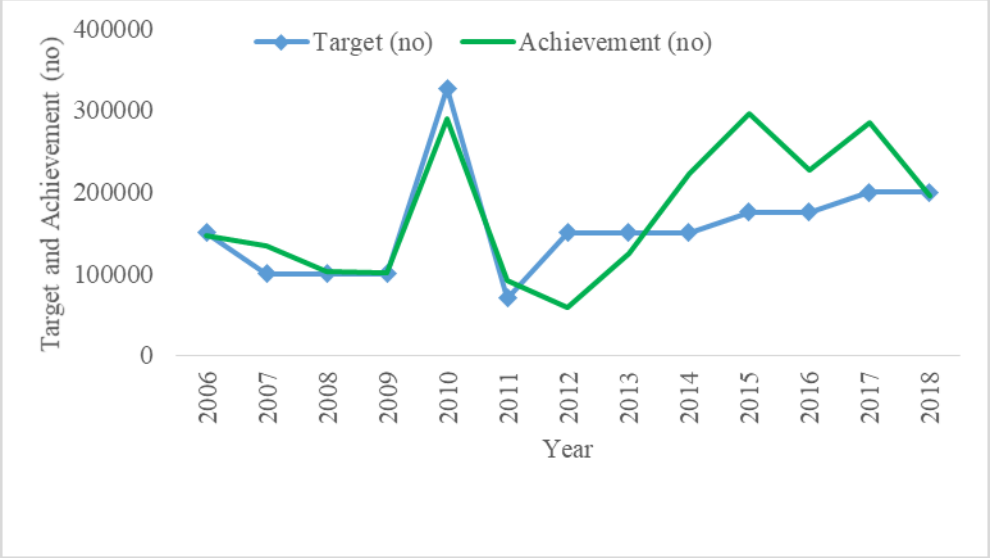

Figure 2. Target and achievement of PBS in NARC from 2006 to 2018

Basic seed production from NARC

Basic seed production from different research stations of NARC from 2006 to 2018 has been shown in Figure 3. The total quantity of basic seed produced was highest in 2017 with about 30 mt of basic seed. In 2013, 2014 and 2015, NARC reached its target and for the rest of the years it was unable to produce targeted basic seeds of potato.

Figure 3. Target and achievement of basic seed in NARC from 2006 to 2018

PBS Distribution by the Private Sector

Distribution of PBS from the private sector through NPDP in 2017/18 is shown in Table 4. NPDP by sourcing from the private sectors distributed a total of 29,605 PBS of four varieties of potato in 2017/18 to different districts. The result revealed that the most preferred variety was Cardinal followed by Desiree, Janakdev, and Khumal Seto.

Table 4. Distribution of PBS from Private Sector through NPDP in 2017/18

District	Address	Cardinal	Desiree	Janakdev	Khumal Seto-1	Total
Bardiya	Basgadhi	7000	2000		1000	10,000
Dang	Private Firm	500		500	500	1,500
Nuwakot	Belkot	2505				2,505
Surkhet	Simta	250				250
Rupandehi	DADO	4000				4,000
Kavrepalanchok	Panchkhal	500				500
Palpa	Rampur			1000		1,000
Dailekh	Dailekh		1000			1,000
Banke	Kohalpur	500				500
Makwanpur	Makwanpur	2000	500		500	3,000
Morang	Pathari			1000		1,000
Dolpa	Tripura Sundari		1600			1,600
Kathmandu	Sankhu	1000	750			1,750
Kalikot	Trivedi	500	500			1,000
Total		18755	6350	2500	2000	29,605

Source: National Potato Development Program, Khumaltar

Similarly, the distribution of PBS from NPRP with the coordination with NPDP in 2017/18 is given in Annex 1. The result revealed that the Cardinal was the most preferred variety followed by Janakdev, Khumal Rato-2, Kufri Sindhuri, Desiree, MS-42.3, Khumal Seto-1, Khumal Upahar, and IPY-8. Recently the Government of Nepal has registered Cardinal, MS-42.3, and Rosita based on their localized preferences and area of coverage (Table 2). However, these varieties were grown widely since the decades even though these were not officially registered because of some technical issues. Yet, their demand, cultivation, and production are higher than other varieties in some specific areas.

Cost of production of basic seeds

The cost of production of first and second-generation basic potato seed (BS1 and BS2) in 2017/18 has been estimated and shown in Table 5. Among different generation of seeds, gross benefit of BS1 was higher than BS2 and BS3. Among the different input costs, for BS1; seed or tuber price accounted for 46%, land rent accounted for 35%, laborer and machinery accounted for 13 % and fertilizer and pesticides accounted for 7% of the total cost of production. Gross benefit per hectare within three months was NRs 14, 66,667 ($ 12,759). Similarly, for BS2; seed or tuber price accounted for 66 %, land rent accounted for 21 %, laborer and machinery accounted for 8%, and fertilizer and pesticides accounted for 5% of the total cost of production. Gross benefit per hectare within three months was NRs 9, 20, 667 ($ 8,009). Similarly, the cost of production of third-generation (BS3) seed was also similar except the cost of seed. The price of BS1 seed was $3.044 Kg^{-1}, price of BS2 seed was $ 0.695 Kg^{-1} and that of BS3 was $ 0.608 Kg^{-1}. Thus, farmers should be encouraged to produce potato seed which not only increases farm income but also enhances the overall productivity of potato in the country and help to reduce the yield gap.

Table 5. Cost of production of first and second generation basic potato seed in 2017/18

Particulars	Unit	First generation basic seed			Second generation basic seed		
		Quantity	Rs/Unit	Total	Quantity	Rs/Unit	Total
Area	Ropani	1.5	15000	22500	6	15000	90000
Tuber Price	Number	3000	10	30000	800	350	280000
NPK	Lump sum	1	1000	1000	250	40	10000
Compost	Lump sum	1	3000	3000	1	10000	10000
Pesticides	Lump sum	1	300	300	1	2000	2000
Land Preparation	Hour	1.5	1000	1500	5	1000	5000
Land Preparation	Man-days	2	750	1500	6	800	4800
Planting	Man-days	4	400	1600	4	500	2000
Earthing Up	Man-days	3	400	1200	10	500	5000
Pesticides/ Irrigation	Man-days	2	400	800			
Harvesting	Man-days	4	400	1600	30	500	15000
Total Variable Cost				65000			423800
Basic Seed Production	Kg	500	350	175000	10000	70	700000
Gross Benefit	NRs			110000			276200
Gross Benefit/Ropani	NRs			73333			46033
Gross Benefit/Hectare	NRs			1,466,667			92,0667
Gross Benefit/Hectare	$			12,759.17			8009.28

Source: FGD 2017/18 *Note: $1= NRs 114.95*

Source seed for seed potato

Varieties, average area, and source of the seed of potato for basic seed in Panauti 3, Kavrepalanchok district is presented in Table 6. The analysis of FGD revealed that the farmers in this locality were cultivating potatoes in irrigated lowlands as well as in rain-fed uplands. In the uplands, potato was also cultivated as an intercrop with maize in around 40 hectares in September-October and harvested in December-January. In lowlands, potato was cultivated in around 10 hectares in January-February and harvested in April-May. The major dominant variety of this area was Janakdev followed by Cardinal, Khumal Rato-2, Desiree, Khumal Upahar, and MS 42.3.

Table 6. Varieties, Average Area and Source of Seed of Potato Basic Seed in Panauti 3, Kavrepalanchok

Potato varieties	Cultivated area (hectare)	Source seed
Janakdev	4	NPRP, NARC
Cardinal	2	NPRP, NARC
Khumal Rato-2	1.25	NPRP, NARC
Desiree	0.75	NPRP, NARC
Khumal Upahar	0.75	NPRP, NARC
MS 42.3	1.25	NPRP, NARC

Source: FGD, 2018

Sources of seed for cultivating ware potato

Farmers obtained their seed tubers from several informal and formal sources. Informal sources included own savings and seed from neighbors and relatives, while formal sources comprised of government's research and development programs, cooperatives, and agro-vets. The seed potato sources were different from farmer to farmer by study locations. Moreover, a considerable amount of seed potato is being imported to Nepal (TEPC 2018; Annex 2) and import is substantial as compared to export (NPDP 2017). The seeds supplied from informal sources were the highest in Solukhumbu (95%) followed by Kavrepalanchok (79%), Kailali (78%), and Jhapa (55%) while seeds from the formal source were the highest in Bara (64%) (Figure 4). This result indicated that most of the farmers were using ware potato as a seed. The findings indicated that informal seed system was predominant (95%) in high hill (Solukhumbu) followed by (79%) in mid hill (Kavrepalanchok). The dominance of formal seed system was higher in central Tarai (Bara), moderate (45%) in eastern Tarai (Jhapa) and low (22%) in far western Tarai (Kailali). Farmers preferred potato varieties with the characteristics of good taste, production potential, color, long storability, early maturity, shape and size, less incidence of insect pests, and availability in their vicinity.

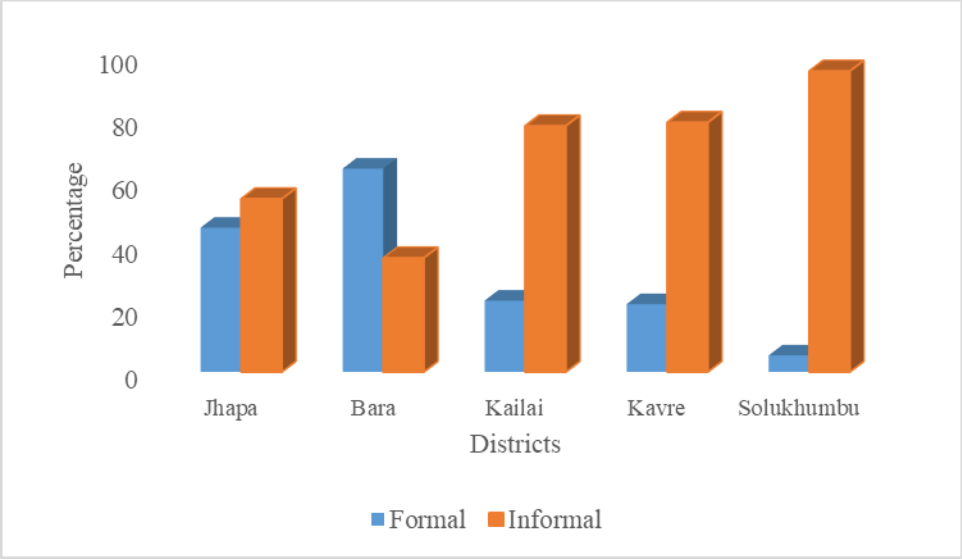

Figure 4. Household sources of potato seed in the study area

Comparative Adoption of Potato Varieties

The extent of adaptation of potato varieties according to the locations has been given in Figure 5 and Annex 3. The number of farmers adopting improved varieties was highest in Kailali (88%) followed by Kavrepalanchok (65%), Jhapa (29%), Bara (25%), and minimum in Solukhumbu.

However, the dominance of local varieties was highest in Solukhumbu (91%) followed by Kavrepalanchok (30%), and minimum in Jhapa and Kailali and null in Bara district. Indian varieties were highest in Bara (75%) followed by Jhapa (67%), Kailali (12%), Kavrepalanchok (5%) and null in Solukhumbu.

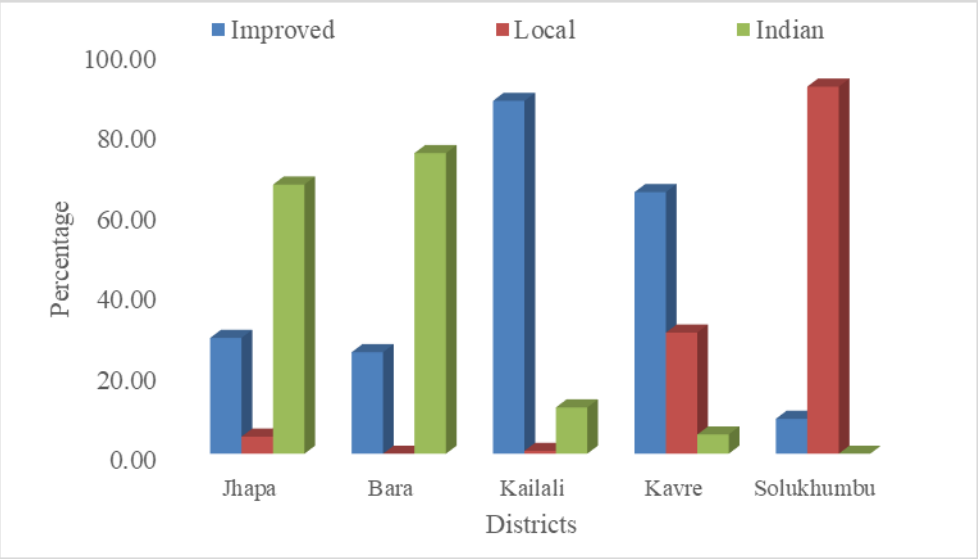

Figure 5. Extent of adoption (% potato farmers) of potato varieties

DISCUSSION

The informal seed system was predominant in high hill (Solukhumbu), modest in mid hill (Kavrepalanchok). The dominance of formal seed system was higher in central Tarai (Bara), moderate in eastern Tarai (Jhapa) and low in far western Tarai (Kailali). This indicates that ecological regions with remoteness and market access including access to new varieties and technical support are important for the functioning of formal and informal seed system

It is evident from the result that the Government of Nepal had released eleven and registered five potato varieties. The seeds supplied from informal sources were the highest in Solukhumbu followed by Kavrepalanchok, Kailali and Jhapa while seeds from the formal source were the highest in Bara. The number of farmers adopting improved varieties was highest in Kailali followed by Kavrepalanchok, Jhapa, Bara and minimum in Solukhumbu. However, dominance of local varieties was highest in Solukhumbu followed by Kavrepalanchok and minimum in Jhapa and Kailali and null in Bara district. Indian varieties were highest in Bara followed by Jhapa, Kailali, Kavrepalanchok and null in Solukhumbu. The FGD analysis revealed that the major dominant variety of this area was Janakdev followed by Cardinal, Khumal Rato-2, Desiree, Khumal Upahar, and MS 42.3.

It is clear that the potato varieties released by GoN earlier are still in production line in farmers' field and not replaced by new varieties. Thus, contributing to increase the adoption lags (Gairhe et al 2017; Timsina et al 2019). A local clone Panauti Golo (red colored round shaped), which was similar to Indian popular variety Lal Gulab, was in existence for three decades. However, it had neither been released nor been registered yet, due to its less area of coverage. One of the reasons farmers using old varieties were due to preferred varieties and quality of seed not available on time (Timsina et al 2016a; Timsina et al 2016b; Timsina and Shivakoti 2018).

In earlier studies, Gairhe et al (2017) showed 57 % and 43 % area were covered by improved and local varieties, respectively in Kavrepalanchok. In case of Jhapa, 40% and 60% area were covered by improved and local potato varieties, respectively. The most important aspiration of seed development might be to develop such potato varieties that fit in farmers' conditions and preferences. However, seeds developed by the formal sector might have less desired characteristics to the farmers in different ecological domains and socioeconomic settings (NSV 2013; Urrea-Hernandez et al 2016). The current productivity of potato is 16.72 mt ha^{-1} which is less than national seed vision projections (Annex 4), and reducing the yield gap is one of the salient ways to meet the demand.

NPRP and some private companies were responsible for the production of PBS of potato in Nepal. The PBS was being promoted by NPDP and presently by NCPVSCD as it collects the demand from potato seed-producing farmer groups with the help of the extension offices of provincial and local government. NPDP not only collected the demand but also acted as a mediator and helped in the potato seed certification at the farmer's level. Seed producing farmers/groups produced basic seeds under the guidance and regular supervision, inspection, and later by certification from a joint team of SQCC, NPRP, NPDP/NCPVSCD, and horticulturist (seed inspector) from Agriculture Knowledge Center (AKC).

The basic seeds were multiplied into other generation seeds by the same farmer group or purchased by other seed growers. Finally, the second or third generations' seed was used for potato production by end-users. However, in some locations, the seed cycle from PBS to generations of BS had not been properly adopted. In many areas, farmers were using ware potato sold by agro-vets which were purchased from unknown sources. It is recommended that a strong mechanism should be developed by which the seed multiplication system could follow a full seed cycle for appropriate use of resources to obtain better economic benefits.

In past, proper seed cycles were not practiced due to lack of designated virus testing facilities and human resources, hindering to meet the national demand for Pre Basic Seed Potatoes production. The area, production, and productivity of ware potato in 2015/16 were 190896 ha, 2551740 mt and 13.37 mt ha^{-1}, respectively; while in 2016/17 the figures reached to 195,268 ha, 273,0294 mt and 13.89 mt ha^{-1}; and in 2017/18, they were 195173 ha, 2881829 mt and 14.77 mt ha^{-1} (MoALD 2019, 2020a).

For basic seeds, demand was estimated to be 0.2 million tons while production was about 3 tons from NPRP. Private sectors' seed production was in fluctuating trend during the study period. It was found that both the public and private sectors' production had not fulfilled the demand. It is also important to consider the preference of farmers for different varietal attributes while producing source seed (Timsina et al 2016b). Public and private partnership to produce, multiply, and distribute the seed is equally important (Gairhe et al 2016, 2021).

The farmers purchased PBS from NPRP for their multiplication into basic seeds. The *Khadyanna tatha Biu Aalu Utpadak Samuha* sold both Basic 1 and Basic 2 potatoes to the other commercial seed producers including the ware potato producers. In 2016/17 about 165 tons of seed tubers were sold and in 2017/18 around 150 tons of basic seeds were sold to cooperatives, farmers

groups, farmers, DADO, and municipalities (Lamjung, Tanahun, Gorkha, Sindhuli, Syanjha). The potato seed producer group received 7000 PBS from the Potato Super Zone with a 100 % subsidy and purchased 3000 tubers for further multiplication.

Quality seeds from technical perspectives were varietal purity, free from diseases (Viruses, Late Blight, Bacterial wilt), free from insect pests (potato tuber moth, red ant, white grub), size (25-50 g) and free from physical injury; while farmers preferred the tubers with more than six eyes, medium to large size (50-100 g) and free from diseases and insect pests for seed purpose. However, farmers often select the smaller potatoes from their harvest to be used as a seed in the next season (Urrea-Hernandez et al 2016).

Lack of pragmatic national policy to boost up potato seed production and income of small-scale farmers and promotion of functional relationship among the various stakeholders of potato, low productivity, meagre access to business growth services, lack of nexus with external markets are major challenges in the potato seed value chain. Successful execution of seed policy and legislation in especially in hills and mountain is needed to impose seed quality control as well as regulate marketing and distribution of varieties in the country (Gauchan et al 2014).

Various instruments and strategies related to farmers' seed systems were issued by the Government of Nepal, of which some are neutral and the most of them are beneficial to the informal seed system (LI-BIRD and The Development Fund 2017). Although ADS (2014) and NSV (2013) highlighted the development and encouragement of high yielding varieties by involving public and private sectors with the vision to increase potato production and productivity, the expected success has not been achieved. The production and productivity are lacking behind as envisaged by national seed vision (Gairhe et al 2021).

Awareness of the value of high quality PBS and basic seed should be created among potato farmers for not using ware potato as seed or even seeds from an unknown source. Since the price of ware potato was much lower than the seed potato, marginal farmers produced the ware potatoes and used them as seeds. Pokhrel (2012) suggested the importance of improving awareness on quality seed production and use among farmers was necessary to maintain quality seed chain. Therefore, it is necessary to change the perception of farmers about the value of the quality seed, seed potato, and ware potato showing the comparative benefits.

CONCLUSION

A high dominance of informal seed system exist in most of the surveyed districts, mostly in high and mid hills and far western Tarai due to poor adoption of new seed, lack of regular transport; remoteness and market accessability to quality improved seeds. As a result, it is likely that potato farmers are compelled to use the low quality ware potato seed. The dominance of informal seed system is due to lack of maintaining the prescribed seed cycle. Likewise, high quality of PBS and basic seeds are misused for ware potato production.

Until now, eleven potato varieties were released and five were registered in Nepal. However, many potato varieties those are popular in different regions of Nepal belongs to old stocks. Some varieties used by farmers without registration need to be registered for the particular domain. The major dominated potato varieties from PBS production and distribution were Cardinal, Janakdev,

Khumal Rato-2, Desiree, Khumal Upahar, MS 42.3, Kufri Sindhuri, KhumalSeto-1, IPY 8, Khumal Ujjwal, Jumli Local, Khumal Vikash, TPS 1, Rosita, TPS 2, Khumal Laxmi and other local varieties.

By producing first-generation basic seed, gross benefit per hectare was found as NRs 14, 66,667 ($ 12,759) and with second-generation basic seed, farmers were able to reap around NRs 9, 20, 667 ($ 8,009) within three months. Therefore, farmers should be encouraged to produce seed potatoes which not only increase farm income but also enhance the overall productivity of the country and help reduce the yield gap. Therefore, the PBS need to be tagged by the potato breeder to address the issues of quality seeds. Further, the supply of source seed of preferred varieties and develop a strong mechanism for the full seed cycle and its proper distribution is critical for enhancing the productivity of potato in Nepal. Similarly, the perception of the farmers should be changed by showing the comparative benefit of growing old and fresh seeds as well as ware potato and seed potato. Improved seed production was inadequate to meet the national demand and the activities implemented in the potato seed sector were not in line with the milestone set in different programs and strategies. Loss of seed cycle and insufficient supply of quality source seed (PBS) were the major problems faced by this sector.

Acknowledgements
We thank ware and seed potato growers in the studied communities and other stakeholders who participated in the study. Fund for this study was supported from Nepal Agricultural Research Council.

Authors' Contributions
SG and KPT were involved in conceptualizing and designing of the research. YNG, SPA, DG, KPU, BPP and PB were responsible for the literature review and provided critical feedback on the manuscript. All authors read and approved the final manuscript.

Conflicts of Interest
The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Publisher's Note
All claims made in this article are those of the authors alone; they do not necessarily reflect the views of any affiliated organizations, the publisher, the editors, or the reviewers.

REFERENCES

ADS. 2014. Agricultural Development Strategy (2015-35). Ministry of Agricultural Development, Singhdurbar, Kathmandu, Nepal.

Bajracharya M and M Sapkota. 2017. Profitability and productivity of potato (*Solanum tuberosum*) in Baglung district, Nepal. Food Secur 8. https://doi.org/10.1186/s40066-017-0125-5

Gairhe S, D Gauchan and K Timsina. 2017. Adoption of improved potato varieties in Nepal. Journal of Nepal Agricultural Research Council 3: 38–44. https://doi.org/10.3126/jnarc.v3i1.17274

Gairhe S, KP Timsina, YN Ghimire, J Lamichhane, S Subedi and J Shrestha. 2021. Production and distribution system of maize seed in Nepal. Heliyon 7(4): e06775. https://doi.org/10.1016/j.heliyon.2021.e06775

Gairhe S, KP Timsina, YN Ghimire, D Thapamagar and S Shrestha. 2016. Tomato hybrid seed production: Initiation of pubic private partnership approach in Agriculture. Nepalese Horticulture 11: 21–28.

Gauchan D. 2019. Seed sector development in Nepal: Opportunities and options for improvement. **In:** Agricultural transformation in Nepal: Trends, prospects, and policy options; pp. 199–229. International Food Policy Research Institute, Springe. https://link.springer.com/chapter/10.1007/978-981-32-9648-0_8

Gauchan D, D Thapamagar, S Gautam, S Singh and U Singh. 2014. Strengthening seed system for rice seed production and supply in Nepal (IRRI-NARC Collaborative EC-IFAD funded project on Seed Net Development). Socioeconomics and Agricultural Research Policy Division, Nepal Agricultural Research Council, Nepal.

Ghimire N. 2005. Adoption of improved potato technology in Chitwan, Nepal. Economic Journal of Nepal 28(3) 188–199. https://www.nepjol.info/index.php/EJON/article/view/174

Kansiime MK and A Mastenbroek. 2016. Enhancing resilience of farmer seed system to climate-induced stresses: Insights from a case study in West Nile region, Uganda. Journal of Rural Studies 47: 220–230. http://dx.doi.org/10.1016/j.jrurstud.2016.08.004

Khatri B, S Shrestha, G Rai and D Chaudhary. 2004. Intensification of potato crop under rice-wheat cropping systems in mid-hills condition of Nepal. **In:** Proceedings of Fourth National Horticulture Research Workshop held on March 2-4, 2004. NARC, Khumaltar, p.10.

LI-BIRD and The Development Fund. 2017. Farmers' seed systems in Nepal: Review of national legislations, Pokhara, Nepal.

MoALD. 2019. Statistical Information on Nepalese Agriculture 2074-75. Ministry of Agriculture and Livestock Development, Government of Nepal.

MoALD. 2020a. Statistical Information on Nepalese Agriculture 2076/77 (2019/20). Government of Nepal, Ministry of Agriculture and Livestock Development, Singh Durbar, Kathmandu, Nepal.

MoALD. 2020b. Working plan for potato production program in Nepal (*Nepalma Aalu Utpadan Karyakramko Karya Yojana 2076*). Ministry of Agriculture and Livestock Development, Government of Nepal.

MoALD. 2022. Statistical Information on Nepalese Agriculture 2077/78 (2020/21). Government of Nepal, Ministry of Agriculture and Livestock Development, Singh Durbar, Kathmandu, Nepal.

NCPVSCD. 2019. Status of potato seed production, demand and supply situation in Nepal Presented in the Workshop of Potato Seed Certification organized by Seed Quality Control Centre.

NPDP. 2017. Annual Report 2073/74. National Potato Development Program, Ministry of Agriculture and Livestock Development, Nepal.

NPRP. 2014. Annual Report 2070/71 (2013/14). National Potato Research Programme, NARC, Khumaltar, Lalitpur, Nepal.

NSV. 2013. National Seed Vision 2013 – 2025. National Seed Board, Seed Quality Control Centre, Ministry of Agricultural Development, Nepal.

Pokhrel S. 2012. Role of DISSPRO and CBSP on current seed supply situation in Nepal. Journal of Agriculture and Environment 13: 53–59. https://doi.org/10.3126/aej.v13i0.7588

Rhoades R. 1982. The incredible potato. National Geographic, 161(5), 668–694.

Rhoades R. 1985. Traditional potato production and farmers' selection of varieties in eastern Nepal (No. 2; Potatoes in Food Systems Research).

Spielman DJ and A Kennedy. 2016. Towards better metrics and policymaking for seed system development: Insights from Asia's seed industry. Agricultural Systems 147: 111–122. https://doi.org/10.1016/j.agsy.2016.05.015

SQCC. 2017. *Biu Bijan Pramanikaran Niredeshika, 2074*. Seed Quality Control Centre. Government of Nepal.

SQCC. 2020. Notified and denotified crop varieties in Nepal. Seed Quality Control Centre (SQCC), Ministry of Agricultural and Livestock Development (MoALD), Kathmandu, Nepal.

SQCC. 2022. Seed balance sheet 2078/079. Seed Quality Control Centre, Nepal.

Sulaiman MI and R Andini. 2013. Lessons learned from seed distribution in Nepal. Procedia Environmental Sciences 17: 20–27. https://doi.org/10.1016/j.proenv.2013.02.007

TEPC. 2018. Trade and Export Promotion Centre, Pulchowk, Lalitpur. Ministry of Industry, Commerce and Supplies, Government of Nepal.

Timsina K, S Gairhe, YN Ghimire, H Poudel, D Devkota, S Subedi and S Adhikari. 2019. Returns to potato research investment in Nepal. Journal of Agriculture and Natural Resources 2(1): 1–13. https://doi.org/10.3126/janr.v2i1.26002

Timsina K, K Kafle and S Sapkota. 2011. Economics of potato production in Taplejung district of Nepal. Agronomy Journal of Nepal 2: 173–181.

Timsina KP, R Bastakoti and G Shivakoti. 2016a. Achieving strategic fits in onion seed supply chain in Nepal. Journal of Agribusiness in Developing and Emerging Economies 6(2):127–149. https://doi.org/10.1108/JADEE-03-2014-0012

Timsina KP, D Jourdain and G Shivakoti. 2016b. Farmer preference for seed quality: A choice experiment with tomato growers in Nepal. International Journal of Value Chain Management 7(4): 368–390. https://doi.org/10.1504/IJVCM.2016.080437

Timsina KP and G Shivakoti. 2018. Vegetables production and marketing: Practice and perception of vegetable seed producers and fresh growers in Nepal. Agric and Food Secur 7(11). https://doi.org/10.1186/s40066-018-0161-9

Timsina KP, G Shivakoti and K Bradford. 2015. Supply situation of vegetable seeds in Nepal: An analysis from policy perspective. Nepalese Horticulture 10: 26–36.

Urrea-Hernandez C, CJM Almekinders and Y van Dam. 2016. Understanding perceptions of potato seed quality among small-scale farmers in Peruvian highlands. NJAS-Wageningen Journal of Life Sciences 76: 21–28. https://doi.org/10.1016/j.njas.2015.11.001

ANNEXES

Annex 1. List showing distribution of PBS from NPRP through NPDP in 2017/18

District	Adress	Cardinal	Janakdev	Khumal Rato-2	Kufri Sindhuri	Desiree	MS 42.3	Khumal seto-1	Khumal Upahar	IPY 8	Total
Kaski	Hemja	200					500				700
Achham	DADO	500	500								1,000
Dadeldhura	PMAMP	1000				1000		500			2,500
Sarlahi	Sarlahi Farm	500		500	503					500	2,003
Palpa	Rapur		1000								1,000
Palpa	Nisdi		500					500			1,000
Banke	DADO	2500									2,500
Lalitpur	FAO		600						600		1,200
Surkhet	Veri Ganga	2000									2,000
Nuwakot	Belkot						495				495
Nuwakot	PMAMP	1525					575				2,100
Humla	Self-Nepal					500					500
Rupandehi	DADO			500					500		1,000
Baitadi	DADO					1000		500		500	2,000
Morang	Rangeli			500							500
Morang	Kanepokhari		500	1000							1,500
Morang	Pathri			2175	2200						4,375
Sindhupalchok	Chautara			500			500				1,000
Kavrepalanchok	Pachkhal Fram		1500		1493						2,993
Kavrepalanchok	Nala		100			100					200
Kathmandu	Sankhu		1000				300				1,300
Total		8,225	5,700	5,175	4,196	2,600	2,370	1,500	1,100	1,000	31,866

Source: National Potato Development Program, Khumaltar

Annex 2. Recent status of export and import of potato seed in Nepal

Particulars	Import		Export	
Year	Quantity (Kg)	Value (NRS)	Quantity (Kg)	Value (NRS)
2016	9,325	235,765	115	21,609
2017	468,548	10,077,122	137,915	1,641,950
2018	355,169	7,529,601	549,255	4,968,750

Source: TEPC 2018

Annex 3. Status showing some potato varieties dominant for cultivation in present study areas

Jhapa		Bara		Kailai		Solukhumbu		Kavrepalanchok			
Varieties	Type	Varieties	Type	Varieties	Type	Varieties	Type	Varieties	Type	Varieties	Type
Lal Gulab	Indian	C 40	Indian	Cardinal	Improved	Namcheli	Local	Janakdev	Improved	kufri Jyoti	Improved
Kanpure	Indian	Arun Gold	Indian	TPS	Improved	Bhotange	Local	Local	Local	Khumal Luxmi	Improved
Khumal Rato -2	Improved	Khumal Rato-2	Improved	Desiree	Improved	Morange	Local	Rato Golo	Local	Khumal Rato	Improved
TPS	Improved	Lal Gulab	Indian	Tharu Alu	Local	Rato Aalu	Local	Dalle	Local	MS 42.3	Improved
Cardinal	Improved	Kufri Sindhuri	Indian	Red Potato	Local	Khumal Rato-2	Improved	Desiree*	Improved	Laliguras	Local
Hollen	Indian	Cardinal	Improved	Khumal Rato-2	Improved	Seto Morang	Local	BTIS	Indian	Lamcho	Local
Local	Local	Rajendra 1	Indian	Trikuli	Local	Khumal Rato-2	Improved	Jhapadi*	Local	Rato Aalu	Local
Rajendra 1	Indian	Satha	Indian	Black potato	Local	Seto Aalu	Local	Cardinal	Improved	White Hybrid	Indian
Kufri Sindhuri	Indian			Karnal	Indian	Desiree	Improved	Khumal Upahar	Improved	DalloAalu	Local
Kufri Jyoti	Indian			Local	Local	Rato Golo	Local	Jhapri*	Local	Ekar Anta Hybrid	Indian
				Rato	Local	TPS	Improved	Khumal Seto	Improved	Golo Aalu	Local
				Red Potato	Local	Khumal Seto-1	Improved	Rato Dallo	Local	Kathmandu local	Local
						Bunga	Local	Khumal Ujwal	Improved		

**Similar in morphological characters*
Source: Household survey 2018

Annex 4. Status and projection details of potato by national seed vision, 2013

Particulars		Status			Projected		
	Unit	2001	2005	2010	2015	2020	2025
Scientific manpower	no			1	3	5	8
Varieties released	no	6	6	8	12	16	20
Breeder seed production	mt	13	13	13	13	13	13
Foundation seed production	mt	216	517	848	1066	1285	1376
Certified/improved seed production	mt	2161	7241	16111	25577	37265	41273
Area	ha			1657	2334	2994	2883
Yield	mt/ha	10.9	13.09	13.89	15.66	17.78	20.45
Crop production	mt	1,472,757	1,974,755	2,542,864	2,966,369	3,380,474	4,019,654
Area coverage under crop prodcution	ha	135,093	150,864	183,076	189,463	190,129	196,539
Seed replacement	%	1	3	5.5	9	14	15
Formal sector seed production	mt	2,161	7,241	16,111	25,577	37,265	41,273
Improved seed area required	ha	283	790	1,657	2,334	2,994	2,883

Note: weight of one tuber is assumed 50 gm. 13000 kg = 260000 tuber
Source: National Seed Vision 2013