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Research Article

Returns to Potato Research Investment in Nepal

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ABSTRACT

Agricultural research plays a significant role in increment in productivity and contributes to food security. Very few studies on the impact of public research spending on different sectors and commodities in Nepal has been documented. This study was designed to estimate the adoption lags of improved potato varieties and benefits generated by potato improvement research in Nepal. More specifically, the study answers two basic questions: (i) whether investment in potato research is justifiable? and (ii) how long is it taking to replace old improved varieties? We took public annual potato research investments of Nepal from the Fiscal year 2001 to 2017 from Nepal Agricultural Research Council (NARC). The household survey was carried out to estimate the potato varieties coverage in Nepal in 2017. Other secondary data were sourced from the Ministry of Finance, Ministry of Agricultural and Livestock Development, FAO stat, Nepal Rastra Bank and NARC to complement the analysis. We have used a simple economic framework to estimate the benefits generated from agricultural research. The estimated benefit and cost streams were used to calculate Benefit-Cost Ratio (BCR) and Net Present Value (NPV). Results showed that the majority of the potato researchers had done research related to crop husbandry (seed production and crop managements); while the limited number of researchers had specialized in breeding activities. The annual growth rate of potato productivity was 214.49 kg per annum per ha which had increased at the rate of 1.76 percent per annum compound growth rate. The results revealed that the average weighted age of improved potato varieties was 21.83 years and each NPR. investment on potato research has given 508 NPR. and NPR. 13760 million NPV at a 12 percent discount factor during the last 17 years. Similarly, the contribution of potato research to GDP and AGDP was found 0.323% and 0.989% respectively. Therefore, future investment and focus should be concentrated on potato research and scaling up activities, and reducing variety adoption lag to obtain additional benefits from potato research investment.

Keywords: Adoption lags, AGDP, benefits, investment in research

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INTRODUCTION

Agricultural research system plays a vital role for the increment in productivity and food security in developing countries (Pardey et al., 2006). As elsewhere in many South-Asian developing countries, agriculture is the largest sector of its economy of Nepal, which contribute 27.58% share of GDP in the year 2017/18 (MoF, 2019). The majority of Nepalese farmers are smallholder combined with livestock where the system whole productivity is very low and inefficient (Shrestha, 2016). Agricultural development can be attained only through the government's considerable investments in agricultural research There is a strong linkage between research investments, innovation and agriculture productivity growth (Fuglie and Heisey, 2007). Agricultural research is the cost-effective way for governments to speed up agricultural development (Beintema et al., 2008) as the rate of return from agricultural research and development investments ranges from 40-50% (Alston et al., 2000). Block (1994) reported that research expenditures contributed to one-third of the growth in agricultural Total Factor Productivity (TFP) in Sub-Saharan Africa. A study conducted by Haggblade (2007) in Zambia has revealed that politically popular programs such as subsidies for agricultural inputs like seeds and fertilizers are less effective to create a substantial return than the investment in agriculture research. The growth in public spending in agricultural research and development has slowed down world-wide (Pardey et al., 2016). Forum for Agricultural Research in Africa (FARA) in 2006 had recommended that public expenditures on agricultural research should be at least 2% of agricultural GDP but only two countries namely South Africa (2%) and Botswana (2.6%) met that target (IFPRI, 2016). In many countries, investment in agricultural research is about 0.5 to 2% of AGDP (Thakur *et al.*, 2007). Government of Nepal has poorly realized the importance of investment in agricultural research in Nepal. For example, Nepal Agricultural Research Council (NARC) is the apex body for agricultural research under the Government of Nepal, annual budget of which was 0.28% of AGDP in 2000, it reduced to 0.25% in 2009 and over the last two decades, it never exceeded 0.30% of agricultural GDP (Stads et al., 2016; PD 2015-2019; MoFA 2019). Low investment in research has negatively impacted the technologies generation and out-scaling to farmers (Gairhe and Acharya, 2017). Similarly, operational budget did not follow a definite pattern and based only on subjective judgment for budget allocation (Gairhe *et al.*, 2017b). The study by Shrestha and Gairhe (2016) recommends that substantial increase in investment in research is needed with balanced and justified manner across the eco-zones and commodities according to their contribution in the output value.

Potato (*Solanum tuberosum*) ranks fourth important staple crop after rice, maize and wheat in Nepal (Gairhe et al., 2017a). Nepal is one of the top twenty countries where potato contributes substantially for the human diet (Subedi et al., 2019). The crop is grown across the broad agro-ecological conditions from 100m to 4000m altitude (Dahal and Rijal, 2019). It is an important staple crop, which enhances the livelihood and food security of poor farmers (Devaux, 2014; Timsina et al., 2011). The productivity of potato can be enhanced through increasing the adoption and reducing the adoption lag of modern improved varieties which impacts on farmer’s income, household food and nutritional security (Gairhe et al., 2017a). National Potato Research Program (NPRP) under NARC has a mandate for conducting research in the potato crop. Until 2019, 11 potato varieties have been released from NARC and 5 were registered in Nepal (Gairhe et al., 2017a; Dhital 2018; MD 2019). Different

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offices of NARC has also been involved in producing source seed and developing potato technologies in Nepal to increase its productivity. However, the returns on the investment in potato research have not been explored yet in Nepal. This research was designed to answer the question (i) whether an investment in potato research was justifiable and (ii) How long is it taking to replace old improved varieties?. In this background, this study estimated the adoption lags of improved varieties and benefits generated by potato improvement research in Nepal. Moreover, it will provide policy guidelines in future investment in potato research in Nepal.

METHODOLOGY

Data and sources

Coverage of NARC released potato varieties were estimated by a household survey conducted by Socioeconomics and Agricultural Policy Research Division (SARPOD) in 2017. Five major potato growing districts, Solukhumbu (high hills), Kavrepalanchowk (mid-hills), Jhapa, Bara and Kailali (terai), were selected purposely based on the potato growing area obtained from Statistical Information on Nepalese Agriculture 2015/16. Within each district, major potato growing pockets were identified in consultation with respective District Agriculture Development Offices. The proportionate random sampling procedure was followed to select the farmers. In total 508 samples were collected from the five districts. Information captured through the survey was complemented with data and information sourced from public agricultural research programs, including ministry of agriculture, research and extension institutes, and universities. Moreover, information was validated and cross-checked after consulting with subject matter experts. The price of potato and exchange rate for the period from 2001 to 2017 was sourced from FAO stat. Similarly, the Consumer Price Index (CPI) was taken from Nepal Rastra Bank.

Analytical methods

Yield growth

Yield growth was estimated by semi-logarithmic regression using data from 2001 to 2017 where gains are expressed as the average percentage change per year.

$$\text{Ln}(Y) = \alpha + \beta X$$

Where α is constant; ln(Y) the natural logarithm of potato yield Y; β is the growth rate of potato yield; X the time (years).

Varietal replacement

The varietal replacement rate can be estimated by using a number of continuous years that a given variety has been sown (Lantican et al., 2016). The weighted average age of varieties was estimated by the following formula.

$$WA = \Sigma (P_{it} N_{it})$$

Where P_{it} is the proportion of the area sown to variety i in year t; N_{it} is the number of years (at time t) since the release of variety i.

Estimating benefit and cost streams

The simple economic framework was used to estimate the annual gross benefit generated by

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potato improvement research following Lantican et al. (2016) with the value of the additional potato production. The physical quantities of additional potato production were transformed into value terms after multiplying with reference potato price.

$B_t = A_t\ Y_t\ P_t$

Where B = value of annual gross benefit attributable to potato improvement research; A = area sown to improved potato varieties released/promoted by NARC; Y= yield gain attributable to potato improvement research; P = the price of potato. There are multiple causes of attributing yield gains in farmers' fields. We have used the aggregate effect of crop improvement from yield potential and yield maintenance. The operational cost involved in potato research was generated from the Planning Division of Nepal Agricultural Research Council (NARC). Both nominal values of benefits and costs were converted into the real term (2001 as a base year) after dividing by consumer price index (CPI).

Benefit-Cost Ratio (BCR) Analysis

This ratio provides a value of benefits and costs that are represented by actual spent and gained. By definition, the BCR should be expressed using present values that are discounted (Shrestha et al., 2019).

Benefit-Cost Ratio = PV of Net Positive Cash Flow/PV of Net Negative Cash Flow

Net Present Value (NPV)

NPV is the cumulative present worth of positive and negative investment cash flow using a specified rate to handle the time value of money. The formula for NPV can be written as:

$$NPV = \sum_{t-1}^{T} \frac{C_t}{(1+r)^t} - C_o$$

Where:

Ct = net cash inflow during the period t

Co= total initial investment costs

r = discount rate, and

t = number of time periods

RESULTS AND DISCUSSION

Research budget and researchers involved in potato research

National Potato Research Program (NPRP) under NARC has a mandate for conducting potato research in Nepal. Besides, NPRP, other nine offices under NARC are also involved in producing source seed and crop management activities (see Appendix 1). Therefore, we have taken all the cost invested for potato research in NPRP and other nine offices in our analysis. The data was used from 2001 to 2017 based on availability. The potato research budget has increased from 1820 to 8165 thousand NPR. in the last 17 years and the compound growth rate analysis showed that there is an increase in operational budget at the rate of 4.24 percent per annum. Even though the budget increased by 3.5 times in the study period, real value (base year 2001=100) of the budget is very low which has increased at the rate of 0.87

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percent per annum (Figure 1). This means the potato research budget did not increase with inflation.

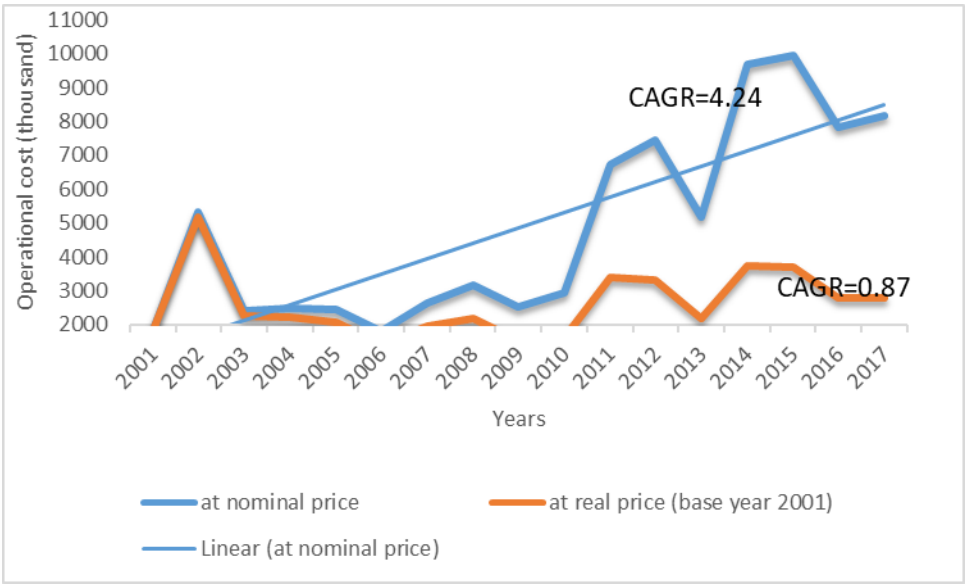

Figure 1: Operational cost of potato research at a nominal and real price

On the basis of full-time equivalent (FTE), the number of researchers involved in potato research was 12 in the public research system in Nepal (Table 1). While calculating researchers involved, all scientists and technical officers from the National Potato Research Program (NPRP) were included but weightage was given based on potato seed production and the number of potato related projects in other offices of NARC (see details in Appendix 1). Results showed that the majority of the researchers were related to crop husbandry (seed production and crop managements) and while a low number of breeders showed little focus on breeding activities which is supposed to be focused more. Shrestha et al. (2012) reported that NARC has more focused on breeding activities in maize and wheat whereas in case of rice it was focused more on crop management compared to breeding activites.

Table 1: Full-time equivalent (FTE) in 2018 in potato research

Thematic area	Researchers involved (FTE)	% Sharing
Breeding	3	25.2
Crop management/husbandry (seed production & production practices)	6.09	51.2
Plant protection	1.65	13.9
Mechanization	0.15	1.3
Socioeconomics	1	8.4
Total	11.89	100

Source: Authors estimation based on researchers involved in potato research at different offices of NARC from 2015 to 2019

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Potato varieties: coverage, growth and adoption lag

NARC has released 11 improved potato varieties with their improved production technologies. Altogether 5 potato varieties are registered in Nepal (see Appendix 3). Among those registered varieties, Cardinal was promoted for four decades in Nepal by the Department of Agriculture (NPDP, 1982). In 2017, the potato was cultivated in 185,879 ha area having 13.9 ton/ha productivity (MoALD, 2018). The annual growth rate of potato productivity was 214.49 kg per annum which was compounding at the rate of 1.76 percent per annum. Even though productivity is increased in the last 17 years, the gap between potential yield and farmers field is still very high (see Appendix 2 & 3). Last five years data from 2015 to 2019 showed that NARC has produced about 27.34 tons of basic seed and 231,531 pre-basic seed each year (see Appendix 1). This indicates that if we follow the seed cycle for seed multiplication, the current source seed produced by NARC can be used to cover at least one-fourth of potato cultivated area at seed rate of 2 tons per hectare (see Appendix 4). Eight private tissue culture lab have been established to produce source seed. In 2019, about 500 thousand pre-basic seeds were produced by the private lab which can be used to increase the area covered by improved potato varieties in the future.

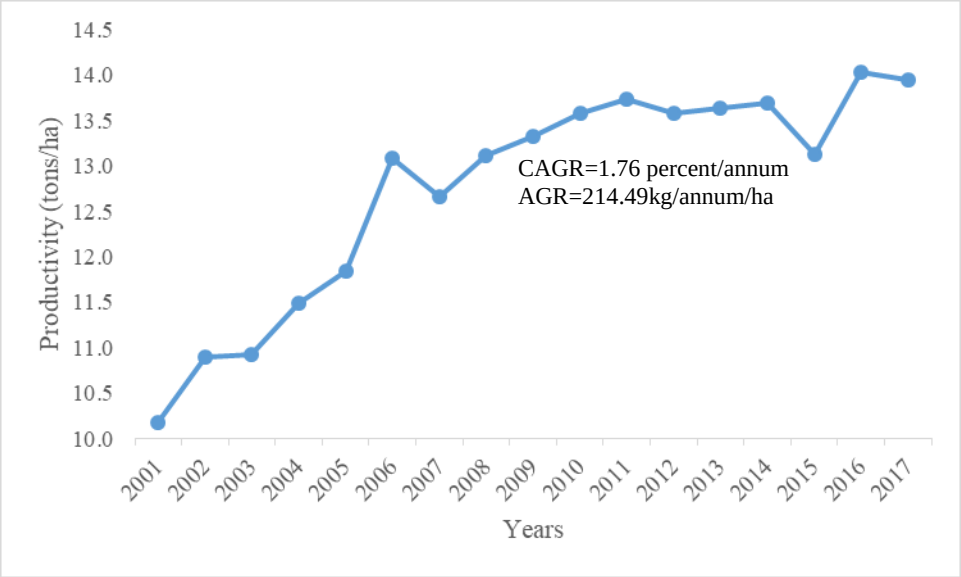

Figure 2: Productivity growth of potato varieties in Nepal (Source: MoALD 2018)

A field survey conducted in 2017 showed that 37% of the total potato area is covered by improved potato varieties released or promoted by NPRP. The major improved potato varieties adopted by farmers in the field were Cardinal (only promoted), Desiree, Janakdev, Khumal Rato-2, Khumal Seto-1, Khumal Laxmi, Khumal Upahar, Kufri Jyoti, Kufri Sinduri, TPS-1, and TPS-2 (see Appendix 2). In addition, 35% area was covered by local varieties, 23% area was covered by Indian varieties whereas 5% area was covered by unknown varieties (farmers were unaware and their seed were also not kept to verify it).

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The study showed the average year of improved potato varieties in the field was 16.72. The weighted average age of improved potato varieties was also estimated using the proportion of the area sown to each variety in time t and the number of years (at time t) since the release of each variety. The result showed the average weighted age of 21.83 years, which means old improved potato varieties were dominating since long back. Lantican (2016) reported that Nepal had more than 14 years of average weighted age of wheat in 1997 whereas it was reduced to 8 years in 2014. He also reported several countries such as Algeria, Bhutan, Ecuador, Jordan, Kyrgyzstan, Morocco, Sudan, Syriac, and Tunisia still have more than 14 years of average weighted varietal age of wheat. Similarly, 18 years of weighted varietal age of rice in Nepal was reported by Gautam et al. (2013) and Velasco (2013). Effective research and extension linkages including community-based organizations, private seed companies and different innovative extension approaches that can link directly to the farmers help to reduce adoption lags (Abebaw & Haile, 2003; Timsina et al., 2018a; Timsina et al., 2018b; Timsina et al., 2019).

Economics of investment in potato research

We have used BCR and NPV while estimating the economics of public investment in potato research in our analysis. Results showed that during the last 17 years from 2001 to 2017, each NPR. investment in potato research has given NPR. 508 and NPR. 13760 million net present value at a 12 percent discount factor. Over this period about NPR. 56491 million returns obtained from potato research while the value was NPR. 8851 million in 2017. At the real price (2001=100), the returns obtained from potato research is comparatively less (see details in Table 2), which indicates that the devaluation of the value of money over 17 years of period. Similarly, the contribution of potato research to GDP and AGDP was found 0.323% and 0.989%, respectively showed that the meaningful contribution of potato research in the national economy. Gauchan et al. (2016) reported that the adoption of Khumal-4 variety of rice, released by NARC, has provided benefits of about NPR. 1 billion (US $ 11 million) per annum at the current price and the farm level adoption of year 2010-2012.

Table 2: Economics of Investment on potato research

Description	At nominal price	At real price
BCR at 12% DF	508	438
NPV at 12% DF (Thousand NPR)	13760461	7755009
Returns (Thousand NPR)+	56491628	28461723
Returns (Thousand NPR)++	8851905	3003171
Contribution of potato research to GDP (%) +++	0.323	
Contribution of potato research to AGDP (%) +++	0.989	

+ include cumulative returns from 2001 to 2017 and ++ includes only returns in the year 2017; +++this is the average contribution of potato research from 2010 to 2017.

CONCLUSION

Investment in agricultural research system contributes to increase productivity and technology development, which ultimately helps to tackle with food and nutritional insecurity. In Nepal, potato, a crucial crop to address those issues, is grown across the broad

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agro-ecological conditions from 100m to 4000m altitude. Until 2018, NARC has released 11 improved potato varieties with their improved production technologies. Moreover, different offices of NARC has been involved to produce source seed and develop technologies related to potato in Nepal. The potato research budget is increased by 3.5 times (1820 to 8165 thousand NPR) in last 17 years but in real value (base year 2001=100), growth of budget is very low; which is found to be increased at a compound growth rate of 0.87 percent per annum. This means the potato research budget has not been increased in response to the inflation. On the basis of full-time equivalent (FTE), the number of researchers involved in 2018 in potato research was 11.89 in the public research system in Nepal. The majority of the researchers had their research related to crop husbandry (seed production and crop management) indicating less focus on breeding activities which is supposed to be focused more. The annual growth rate of potato productivity was 214.49 kg per annum in the last 17 years, which still showed the large gap between potential yield and farmer's field. This might be due to the higher average age of improved potato varieties in the field. The weighted average age of improved potato varieties were 21.83 years, which means older improved potato varieties were dominating since long back.

Economic analysis showed that during the last 17 years from 2001 to 2017, each NPR. investment on potato research has given NPR. 508, and NPR. 13760 million net present value at 12 percent discount factor. Over this period, about NPR. 56491 million was obtained from potato research while it was NPR. 8851 million in the single year 2017. The returns obtained from potato research at the real price (2001=100) is comparatively less, which indicates the devaluation of the value of money over 17 year's period. Similarly, the contribution of potato research to GDP and AGDP was found 0.323% and 0.989%, respectively which showed the significant contribution of potato research in the national economy. Therefore, more investment in potato research focusing on research activities and concentrating to reduce variety adoption lags would be an appropriate strategy to get additional benefits from potato research and development in Nepal.

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Authors contribution
KPT was the lead investigator and the initiator of the study. SG, HP, DD, SS and SP were responsible for literature search, data generation and drafting of the manuscript. KPT and YNG were responsible for overall study design and finalization of the manuscript. All authors read and approved the final manuscript.

Conflict of Interest
The authors declare that there are no conflicts of interest regarding publication of this manuscript.

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APPENDICES

Appendix 1: Potato source seed production in NARC in last five year (2014/15 to 2018/19)

Office Name	Unit	2018/19	2017/18	2016/17	2015/16	2014/15	Average
ARS, Jaubari	Ton	9.42	10.9	12	3		8.83
Horticulture Research Station Rajikot, Jumla	Ton	8.2	8.18	5.12	5.08	7	6.72
Horticulture Research Station, Dailekh	Ton	0.5					0.50
Horticulture Research Station, Malepatan	Ton	2.05	2.3	5.39	4.42	0.14	2.86
National Potato Research Program, Khumaltar	Ton	3.88	3.83		3.91	3.03	3.66
RARS, Doti	Ton	0.73		0.7	1.06		0.83
RARS, Lumle					0.04		0.04
RARS, Khajura	Ton	0.48					0.48
RARS, Parwanipur	Ton	3.02	1.94	1.31	2.23	2.82	2.26
RARS, Tarahara	Ton	3.45	4.91	4.91	5.8	4.45	4.70
Total potato seed	**Ton**	**31.73**	**32.06**	**29.43**	**25.54**	**17.44**	**27.24**
Pre-basic potato seed	**Number**	**150055**	**200583**	**284422**	**227169**	**295426**	**231531**

Appendix 2. Status of potato varieties adoption in Nepal

Varieties	Area coverage (%)
Improved+	**37**
Cardinal++	9.4
Desiree	2.0
Janak Dev	14.9
Khumal Laxmi	0.2
Khumal Rato-2 (I-1039)	4.8
Khumal Seto-1	0.4
Khumal Ujwal	0.1
Khumal Upahar	0.3
Kufri Jyoti	0.3
Kufri Sinduri	1.1
TPS- 1 TPS- 2	3.5
Indian	**23**
Local	**35**
Unknown	**5**

Field survey 2017, ++Promoted by public research system

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Appendix 3: Released and registered potato varieties in Nepal

S. N.	Name of released varieties	Year of released	Yield potential (t/h)	Maturity days	Recommended domain
1	Khumal Bikas	2018	25	100-120	Mid to High hills
2	Khumal Upahar	2014	24	100-120	Terai and Mid hills
3	Khumal Ujjwal	2014	25	100-120	Mid to High hills
4	Khumal Laxmi	2008	28	100-140	Terai, Hill
5	IPY-8	2008	27	100-120	Terai, Hill
6	Khumal Seto-1	1999	38.7	110	Terai, Foot hills, Mid and High Hills
7	Khumal Rato-2	1999	36.2	95	Terai and Inner Terai
8	JanakDev	1999	39.4	110	Terai, Foot hills, Mid and High Hills
9	Desire	1992	18	90-120	High & Mid Hill, Terai
10	Kufri Sindhuri	1992	23	110-120	Mid Hill and Terai
11	Kufri Jyoti	1992	23	110-120	High and Mid Hill
	Name of registered varieties	**Year of released**	**Yield potential (t/h)**	**Maturity days**	**Recommended domain**
1	Cardinal	2019	18-30	90-100	Terai to Hills (From 100 to 4000 m)
2	Rojita	2019	10-14	100-110	Eastern and Central High Hills (From 1600 to 3500 m)
3	MS 42.3	2019	10-24	110-120	Terai to Hills (From 100 to 1600 m)
4	TPS-1	2014	35-40	110-120	Irrigated area of Terai and Mid Hill
5	TPS-2	2014	35-40	110-120	Irrigated area of Terai and Mid Hill

AICC 2018; Dhital 2018 & MD, 2019

Appendix 4: Improved seed production estimation from source seed produced from NARC

Years	PBS seed production (number)	Basic seed 1(tons)	Basic seed 2 (tons)	Basic seed 3 (tons)	Improved seed (tons)
2015	295426	114.1678	1141.678	11416.78	114167.8
2016	227169	97.5807	975.807	9758.07	97580.7
2017	284422	85.3266	853.266	8532.66	85326.6
2018	200583	92.2349	922.349	9223.49	92234.9
2019	150055	76.7465	767.465	7674.65	76746.5

Note: Seed multiplication ratio from breeder to foundation 1:6; from foundation to Improved 1:10. Weight of one tuber is assumed 50 g.