

Research Article

Replacement of concentrate mixture with different levels of water hyacinth (*Eichhornia crassipes*) in basal diet on feed intake and production performance of piglets

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ABSTRACT

An experiment was conducted on weaned piglets at Piggery Research Unit of Regional Agricultural Research Station (RARS), Tarahara, Sunsari from 12 September to 4 December 2019 for 84 days after adjustment period of seven days. Twenty piglets after weaning of 4-6 months age were allocated into four treatments each with 5 replications by using Completely Randomized Design. Four type of experimental diets were composed for experimental piglets. Piglets of T1 (control) group were provided adlib concentrate mixture, 95% concentrate feed + 5% water hyacinth (WH) were given to T2 group, 90% concentrate feed + 10 WH were offered to T3 group and piglets of T4 group were fed 85% concentrate feed + 15% WH as per their daily requirement. Feed and water hyacinth intake were recorded daily and body weight gain was measured once a week. Experiment revealed that feed and WH intake was highly significant ($p < 0.001$) among treatment groups. Highest total body weight gain was obtained in control group (T1) (37.66 kg) followed by T3 (34.91 kg) and T2 (34.25 kg) which was non-significant among diet groups. Similarly, highest average daily gain was observed higher for T1 (control) group (448 g /day) followed by T3 and T2 group (415.59 and 407.73 g/day, respectively). Feed Conversion Ratio (FCR) was observed almost similar in all treatment groups (1:2 kg). Experiment suggested that concentrate mixture can be safely replaced with WH up to 15% without any adverse effect on body weight gain.

Keywords: Feeding, pig, weight gain, water hyacinth

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INTRODUCTION

Pig farming has been accepted socially and culturally by certain ethnic groups in Nepal. Pig farming trend is changing gradually due to urbanization some commercial and modern pig farming recently started in Nepal. The indigenous pig breeds of Nepal are Chwanche, Hurrah, Bampudke, Pakhribas black and Dharane Kalo Bangur etc. Exotic breeds of pigs such as Hampshire, Duroc and Yorkshire etc. are imported in Nepal since 1957 AD. The pig

population of Nepal is estimated to be 1.43 million and producing 28214 MT pork per annum (Krishi diary, 2019).

Pork consumption has grown tremendously over the years across the Nepal, but production has not responded sufficiently to meet demand. One of the main reasons for rising pork demand is removal of cultural barriers that prevented people from consuming the meat. Most of the people who are growing pigs are overseas migrant workers who have returned home for good. Consumption of pork is going up in the country, as protein intake is continuously increasing due to rise in income level. Today, people of almost every ethnic background consume pork, which is pushing up demand for this meat product (Thapa, 2017).

In swine production, feed alone represent 70-75% of total cost of production. In intensive pig production, pig directly compete with human being for feeding, since conventional fattening is based on the feeding of cereals like maize, wheat, oats, barley etc. along with other protein, mineral and vitamin supplements. Farmers are unable to support costly feeding program because of high cost of cereals and oil cakes. Novel feed ingredients are not traditionally been used for swine feeding. However, these can be used as supplemental ingredients to the basal ration in order to reduce the feed cost. To get profit from swine farming, one has to plan carefully to get maximum feed efficiency from a particular diet. One can easily reduce the

feed cost using many locally available novel feed resources. The novel feeds can be used as supplemental ingredients which are available in large quantities at cheaper rate. Many novel feeds contain anti-nutritional factors which reduce the productivity of animals by hampering the digestibility of nutrients (Ngullie, 2019).

WH has perhaps been a subject of more indecisive study than any other aquatic plant in recent years. Several scientists (Rogers and Davis, 1972; Cornwell *et al.*, 1977; Soerjani, 1984) reported that WH has been utilized as livestock feed, bio-fertilizer, sewage purifier and biogas production, paper and fiber (Bagnall *et al.*, 1974), and dried hyacinth can be used as animal feed for cows, pigs, goats, etc (CWSCB, 1982). WH is one such new feed resource for pig which foliage and stem is commonly used as a supplementary feeding for pigs (Le *et al.*, 2006 & Jafari, 2010). A maximum inclusion rate of 6–7% (on DM basis) was considered economically viable because of presence of anti-nutritional factors in it (Mako *et al.*, 2011).

WH is an invasive aquatic plant in most countries all over the world. It has been recognized for its high nutritional value (Poddar *et al.*, 1991). According to an analysis by Abobarkr *et al.* (1984), all of the essential amino acids were present at high levels in the leaf protein isolates of water hyacinth. One of the advantages of using WH in pig diets is its lysine content (Abobarkr *et al.*, 1984), the first limiting amino acids for pig. WH have a water content of over 90%. The crude protein contains between 10 and 26%, but the leaves contain higher levels (about 38%). The mineral content depends directly on the water where the hyacinth grows, but the mean value ranges from 17 to 26%. The fibre level averages about 20 percent has made WH interesting for use as fodder to cattle, goats, pigs, ducks and tilapia fingerlings (Tham, 2015; Lareo & Bressani, 1981).

However, published data are limited on its possibility to use for pig diet. Therefore, this experiment was carried out in order to assess the possibilities of replacing concentrate

mixture with different levels of WH to a basal diet on growth performance and feed intake of piglets.

MATERIALS AND METHODS

Experimental site and animal selection

An experiment was conducted on weaned piglets at Piggery Research Unit of Regional Agricultural Research Station, Tarahara, Sunsari from 12 September to 4 December 2019 for 84 days after adjustment period of seven days. Twenty piglets after weaning of 4-6 months age were allocated into four treatments each with 5 replications by using Completely Randomized Design. Experimental piglets were kept in cemented floor in group according to treatment. All experimental animals were drenched with Fenbendazole at the rate of 5 mg/kg body weight against internal parasites at the beginning of the experiment.

Diet composition

Compound feed containing 16% crude protein and metabolizable energy at the level of 2700 Kcal/kg were procured from Sagar Feed Industry, Itahari, Sunsari and water hyacinth was collected in the premises of Piggery Research Unit of RARS, Tarahara and National Buffalo Research Program, Tarahara, Sunsari. The WH plants were harvested lush green using local canoe. The plants were washed clean with the water and packed in plastic bags before taking them ashore. The root and petioles were immediately removed and discarded. After washing, leaves and stem were immediately chopped to an average size of about 2 cm in length, dried in the shed until crispy while still retaining the greenish coloration and dry matter was achieved 25-30%. The dried WH was thereafter incorporated into basal diet at different levels of inclusion to replace the concentrate mixture weight. All diets were balanced for calcium and phosphorous as per the requirements.

Experimental diets

=Four experimental diets as of treatments were thus prepared to feed the experimental animals (Table 1).

Table 1: Experimental diets

Treatments	Diets
1	Adlib Concentrate feed without WH
2	95% concentrate mixture + 5% WH
3	90% concentrate mixture + 10% WH
4	85% concentrate mixture + 15% WH

Feeding regime

Required amount of concentrate mixture and WH was mixed and provided twice a day (morning and evening) in group basis to the experimental animals. The experiment animals had free access to clean drinking water.

Chemical analysis

The samples of concentrate mixture and WH were sent to the Animal Nutrition Division, NARC, Khumaltar, Lalitpur for proximate analysis. Representative samples were analyzed for Dry Matter (DM), Crude Protein (CP), Crude Fibre (CF), Ether Extract (EE) and Ash contents (TA). The DM was determined by oven drying at 100°C for 24 hrs. Crude protein of the

samples was determined by using the Kjeldahl method. Ether extract was determined by using Soxhlet apparatus. Total ash content was determined by ashing at 550⁰C in muffle furnace for 16 hrs. (AOAC, 1980). Ether extract of the samples was determined using the Van Soest methods (Goering HK and Van Soest, 1970).

Observation recording

Total feed offered to the experimental piglets was recorded daily in group basis and refusal in the next morning. The body weight gain of individual piglet was measured at seven days interval in the morning before feeding.

Data analysis

Data of feed intake and body weight gain were analyzed by One-way Annova test for every measurement using statistical package SPSS, version 16.

RESULTS AND DISCUSSION

Chemical composition of feed ingredients

Chemical composition of feed ingredients is presented in Table (2).

Table 2: Nutrient of feed ingredients in dry matter basis

S/n	Ingredients	DM	OM	TA	CP	CF	NDF	ADF	ADL	HC	Cellulose
1	Water hyacinth	18.61	96.69	3.31	13.51	NA	59	28.45	5.35	30.55	23.09
2	Concentrate mixture	89.31	93.48	6.52	24.81	8.32	NA	NA	NA	NA	NA

Note: DM - dry matter, OM - organic matter, TA - total ash, CP - crude protein, CF- crude fibre, NDF- neutral detergent fibre, ADF - acid detergent fibre, ADL- acid detergent lignin, HC - hemicellulose

Feed intake

Table 3 showed that intake of WH was correlated with levels of inclusion. Intake was increased as per the rate of inclusion level which was highly significant ($p < 0.001$) among diet groups. Highest intake of concentrate mixture was noted in T1 (1050 g/day/animal) followed by T2 (1017.1 g/day/animal) and T3 (963.42 g/day/animal) which was significant ($p < 0.05$) between T1 and T4 groups and T2 and T4 groups. Feed intake of T3 and T4 groups was noted insignificant. Similarly, highest FCR (DM intake: weight gain) was observed for T1 (control) group (2.14:1kg) followed by T3(2.17: 1kg) and T4 (2.26:1 kg). The feed intake of the experimental animals has been presented in Table 3.

Table 3: Feed intake of experimental piglets, g (Mean±SD)

Parameters	Treatments			
	T1 (Control)	T2 (5% WH)	T3 (10% WH)	T4 (15% WH)
Water hyacinth intake, g	0	53.52±17.38	107.0±34.84	160.53±52.21
CV (%)	0	32.48	32.56	32.52
F value			386.94	
P value			0.000	
LSD			4.97	
Concentrate intake, g	1050.23±378.2 ^d	1017.1±330.25 ^d	963.42±312.96	909.7±295.86 ^{ab}
CV (%)	36.01	32.47	32.48	32.52
F value			2.99	
P value			0.031	
LSD			50.35	
Today dry matter intake, kg	80.64	79.44	75.76	72.44
FCR (DM intake: weight gain), Kg	2.14:1	2.32:1	2.17:1	2.26:1

Body weight gain

Table 4 showed that initial body weight of experimental piglets ranged from 10-11 kg which was non-significant among diet groups. By the end of experiment, highest total body weight gain was obtained in control group (T1) (37.66 kg) followed by T3 (34.91 kg) and T2 (34.25 kg) which was also non-significant among diet groups. Similarly, highest average daily gain was observed higher for T1 (control) group (448 g /day) followed by T3 and T2 group (415.59 and 407.73 g/day, respectively). The body weight gain trend of the experimental animals is presented in Table 4.

Table 4: Body weight gain of experimental piglets, kg (Mean±SD)

Parameters	Treatments				CV	F value	P value
	T1 (Control)	T2 (5% WH)	T3 (10% WH)	T4 (15% WH)			
Initial weight, kg	11.02±0.58	10.75±2.14	10.51±2.12	10.3±1.45	13.58	0.249	0.861
Final weight, kg	48.68±2.36	45.0±6.57	45.42±5.64	42.27±6.34	10.92	1.463	0.262
Total Weight gain, kg	37.66±2.01	34.25±4.35	34.91±4.72	31.97±5.62	13.14	0.854	0.481
Average daily gain, g	448.33±2.39	407.73±4.78	415.59±5.61	380.59±6.69	12.83	1.452	0.267

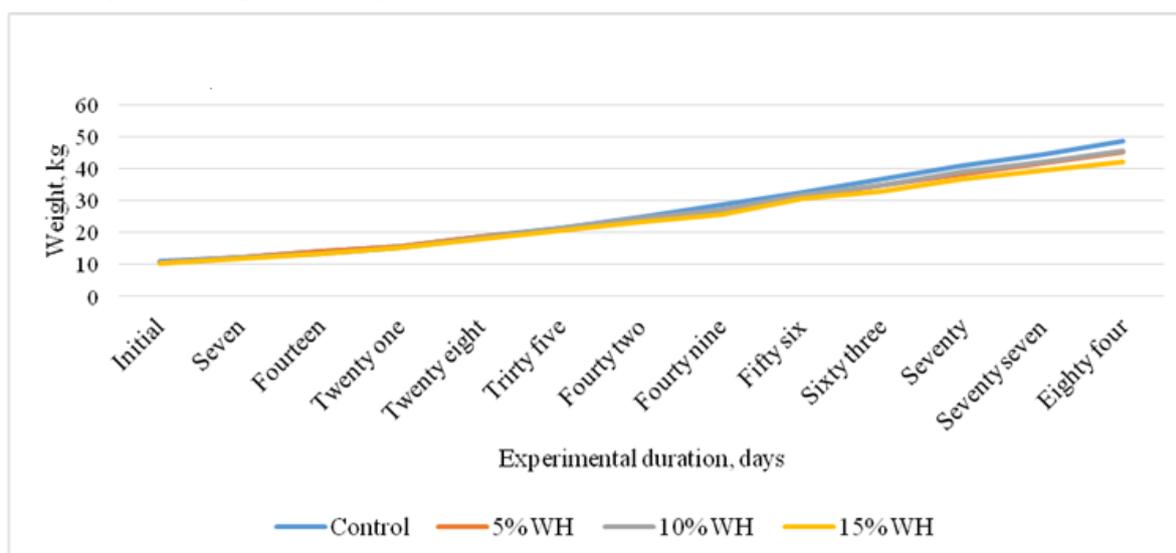


Figure 1: Body weight gain trend of experimental animals

Cost benefit analysis

Cost benefit analysis is a systematic approach to estimating the strength and weaknesses of alternatives used to determine option which provide the best approach to achieving benefits while preserving saving (David *et al*, 2013). Benefits and costs in cost benefit analysis are expressed in monetary terms and are adjusted for the time value of money; all flows of benefits and costs over time are expressed on a common basis in terms of their net present value (David *et al*, 2013).

The pellet feed used in the experiment was procured from the Sagar Feed Industry, Itahari, Sunsari at the rate of NRs 45 / kg. The labor cost was taken considering the rule and regulations of Nepal Agricultural Research Council (NARC) for the fiscal year 2076/77. One labor was hired for the 91 days for feeding to experimental animals (20), cleaning of shed, to measure the feed refusal daily, to measure the body weight gain at seven days interval, to provide the fresh drinking water and to help the veterinarian to treat the sick animal if that occurred. The wages rate of labor per day was NRs 517.0. The total labor cost was calculated NRs 517 / day x 91 days (NRs 47047.0) and divided by 20 experimental animals (47047/20 =2352.25). After completion of experiment, experimental animals were sold out to the butchers @ NRs 220 /kg live weight. If the experimental animals had been sold to breeder farmers the selling rate might be higher than NRs 220.0. Cost benefit analysis showed that replacement of concentrate mixture with WH at the rate of 10% was comparatively beneficial than that of 5 and 15% replacement (Table 5).

In this study, cost benefit analysis was done by considering feed and labor costs and income from sales of experimental piglets. The detail of cost benefit is presented in Table (5).

Table 5: Cost benefit analysis, in NRs

Parameters	Treatment			
	Without Water hyacinth (T1)	5% concentrate replaced with WH (T2)	10% concentrate replaced with WH (T3)	15% concentrate replaced with WH (T4)
Feed intake				
Concentrate mixture cost	4064.4	3959.77	3731.58	3520.53
Water hyacinth cost	0	0	0	0
Labor cost	2352.35	2352.35	2352.35	2352.35
Total expenditure	6416.75	6312.12	6083.93	5872.88
Income from sales of animal	10709.6	9900.0	9992.4	9299.4
Net income	4292.85	3587.88	3908.47	3426.52

DISCUSSION

Experiment revealed that there was highly significant ($p < 0.001$) effect of replacement of concentrate mixture with WH in different levels on feed and WH intake during entire experimental period. FCR of all experimental group was almost similar (2:1kg). Barman *et al* (2015) conducted an experiment on piglets by feeding three types of experimental diets containing WH at the rate of 0, 5 and 10 % by replacing maize and designated as T1, T2 and T3 groups, respectively. In that study they found that there was no difference in DM intake (kg/d) across the groups. Digestibility coefficients (%) of nutrients were similar across the groups except crude fibre digestibility which was reduced significantly in T3 group in comparison to other two groups. The average body weight gain (g/day) was statistically similar across all groups. The feed conversion ratio and cost of production per kg live weight was similar in all the groups. However, feed cost per kg gain was significantly ($p < 0.05$) reduced in comparison to T1 (control) group. Moreover, they concluded that WH foliage could replace 5% maize in ration of crossbred grower pigs without any adverse effect on body weight gain. Ngullie, L (2019) reported that WH foliage is commonly used as a supplementary feeding for pigs in smallholder farms in Asia. It was reported that water hyacinth foliage could replace 5% maize in ration of crossbred grower pigs without any adverse effect on nutrient utilization.

Akankali and Elenwo (2019) conducted an experiment on piglets 24 large white weaner pigs of both sexes with initial live weight of 10-12 kg were randomly allocated to four dietary treatments by using CRD and each treatment replicated thrice with two piglets per replicate. A balance basal diet was formulated with soybean meal (SBM) as the protein source (T1 control), in T2, T3 and T4 SBM was replaced with WH in the levels of 10, 20 and 30%, respectively. Experiment revealed that there was no significant influences of animal studies, growth and performance are important the treatments on average weekly feed conversion indices in evaluating productivity. The growth and ratio (weight: gain) among the treatment group performance indices of the pigs evaluated in the study was non-significant with increasing levels of WH. Similarly, analysis of variance showed the difference between the treatment groups ($p > 0.05$) influence of WH on average final weight.

In case of growth performance, this study showed that there was no significant effect of different levels of concentrate mixture replacement with WH on growth performance of piglets from beginning to end of the experiment, however, highest total body weight gain and average daily gain was obtained in T1 (control) group (37.66 kg and 448.33 g/day, respectively) than that of other treatment groups. This could be as a result of fairly adequate

crude protein and amino acid profile of WH which was supposedly sufficient enough to cause the possible weight increment. This agrees with the findings of (Peo *et al*, 2001 and Parr *et al*, 1996) who reported that pigs fed diets of protein concentration varying from 15%-20% CP adequately supplemented with lysine and methionine, gained sufficient weight.

Bohman (2001) reported that pigs fed with 20% crude protein produced weight gains and feed efficiency comparable to those fed 16% crude protein. Moreover, pigs have a unique ability to eat, digest utilize, and convert poor-quality unconventional feed ingredients to high quality meat. The good weight gain of the pigs fed dietary treatments could also be attributed to the presence of non-toxic or non-anti-nutritional factors in water hyacinth which would have inhibited growth. And, this agrees with Gilster and Wahlstrom (1999) who reported that WH contains no toxic or anti-nutritional substance that depresses growth. Also, Perason *et al* (2001) reported that as the particle size of feed containing crude fibre becomes smaller, better weight gains are obtained. The chopping of the WH to small sizes to pass through a 0.5mm screen after drying, could have aided in digestion, utilization of the plant and the consequent good weight gain.

Ajuogu (2019) conducted an experiment to determine the impact of feeding WH-based diets on the organ weights and carcass quality characteristics of weaner pigs. The weaner pigs were fed WH based meal at dietary levels of 0%, 10%, 20% and 30% inclusion Levels to replace SBM in the experimental diets. The result of the organs (Liver heart, kidney, spleen and lungs) and carcass weights revealed no significant difference ($p>0.05$) between the treatment groups and the control. The result of the lean fat deposit and back-fat thickness showed a significant difference among the pigs used in the study. The control diet (0%WH) had the highest fat content and diet IV (30%WH) had the least fat content. Since the lean fat deposit and back-fat thickness are a reflection of the fat deposits in the pig WH produced better (lean fat) pork than Soya bean meal. He concluded that WH had no poisonous impact on organs. Also, SBM has a better significant influence in terms of the fat deposit than water hyacinth.

According to Suharsono (1979), mixing of WH up to 15% into the rations did not significantly affect pig growth and it could reduce the prices of the ration because reducing the amount of concentrate was needed.

A study conducted by Men *et al*. (2006) revealed that pig had shown good acceptance for WH and the pigs fed on WH based diets had better carcass appearance than the common diet fed pigs in Vietnam, because, pork exhibited low back-fat and body fat with excellent meat productivity (Choi, 2004; Kim, 2012). Inclusion of 5-15% of WH biomass in the pig feed did not affect daily gain in feed intake, fat thickness and loin eye area compared to control (Cui *et al.*, 2004). As an animal feed, it has been used fresh. In experiments with pigs in southwest Colombia, fresh water hyacinth was substituted for 20% of commercial feed without toxicological problems or effects on rate of growth (Lareo and Bressani, 1981). Ngullie, L (2019) reported that WH foliage is commonly used as a supplementary feeding for pigs in smallholder farms in Asia. It was reported that WH foliage could replace 5% maize in ration of crossbred grower pigs without any adverse effect on nutrient utilization. Xing *et al*. (2001) investigated the appropriate proportion of WH in pig feed and analyzed the economic benefits. The growing pig reached a standard weight of 90 kg, and the optimal ratio of concentrate to WH was 1:0.5 in the previous period and 1:1 in the later period. Compared with the control group, each pig saved 8184 kg of refined material, resulting in cost savings

of 9.95 Chinese yuan. Tacio (2009) reported that 5% of water hyacinth in the total diet of pigs leads to significantly weight gains. But feed containing 30% of more of hyacinth can reduce weight gain by over 90%. These tests showed that water hyacinth as a feed for animals must be used with great care.

CONCLUSION

It can be concluded from this study that one of the real long term, economically viable and environmentally friendly solution to the WH menace was can be utilized it as feed ingredient in swine diets up to 10%. This will help in recycling WH into a useful feed resource, thereby help in reducing cost of feeding. However, further validation of this findings in farmers field is necessary.

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Authors' Contributions

MRT was the lead investigator and the initiator of the study. MK, LNP and NP were responsible for literature search, data generation and drafting 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

Appendix 3: Released and registered potato varieties in Nepal

S. N.	Name of released varieties	Year of released	Yield potential (t/ha)	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/ha)	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.