Participatory varietal selection of potato and agronomic performance with farmers' feedback on new varieties

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ABSTRACT

Potato (Solanum tuberosum L.) is one of the widely produced, consumed and traded horticultural crops in Bhutan. Hence, potato cultivation has helped to transform the Bhutanese agriculture from subsistence to an emerging market-oriented agriculture. However, its productivity has remained stagnant over the years due to lack of varietal diversity and degeneration of seed quality. Therefore, variety development research was conducted to increase yield and provide alternative varieties. The advanced evaluation trial using mother and baby approach was conducted using suitable International Potato Center (CIP)-originated potato clones of 399053.11, 394034.7, 394611.112, 396034.268, 397196.3, 392797.22 and 303381.30 and Desiree as the local check (control) at Bumthang and Khangma in 2015. Following the evaluation and release of a new potato variety, three demonstration trials were conducted in Chukha, Haa and Wangdue districts to compare the yields of two new varieties with Desiree. When the clones were assessed based on yield and preference ranking by the farmers, 397193.3 and 392797.22 clones outstood as high yielders and most preferred ones, while 394034.7 was considered as the least yielder and least preferred clone in Bumthang. The two clones (397193.3 and 392797.22) had significantly ($P<0.05$) high yield and were the most preferred ones compared to Desiree in both the mother and baby plots. Having fulfilled all the research requirements, 392797.22 were released in June 2017 as Yusi Maap to address yield stagnation, as an alternate red-skinned variety. Besides being a micro-nutrient-dense variety, Yusi Maap has moderate resistance to late blight. In three demonstration trials, Desiree yielded the least among the three varieties. Analysis on the farmers' preference ranking showed that Yusi Maap was most preferred in three locations probably due to the red skin and better yield. The results of this study is has potential to positive impact potato production and enhance farmers' livelihood through higher yields.

Keywords*: Participatory varietal selection, Bhutan, Yusi Maap, organoleptic assessment, malnutrition*

1. Introduction

Globally, potato (*Solanum tuberosum L.*) is the fourth most important crop after wheat, rice, and maize. Apart from its wide adaptability, it has the capability to provide more nutritious food from less land in less time than other crops such as wheat, maize or rice (CIP 1984). In

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Bhutan, potato is one of the widely produced, consumed and traded horticultural crops (Department of Agriculture 2017). This is possibly due to the existence of favorable conditions for growing high quality potato in the country. (Joshi & Gurung 2009). Potato is mostly grown between 2000 and 3500 m above mean sea level (m.a.s.l) and is the most important crop for the farmers living above 2500 m.a.s.l. (Roder et al 2008). About twenty two percent of the rural households cultivate potato as it is the only non-cereal food crop, cash crop and vegetable. It contributes to rural household income more than any other horticultural crops (RNR Census 2000). Over the past four decades, potato cultivation has picked up fast and has transformed the Bhutanese agriculture from subsistence to an emerging market-oriented economy (Roder et al 2008). Famers in some Dzongkhags, for example, Bumthang and Haa rely on potato crop for their livelihood since they buy cereals through the sale proceeds of potato and thus potato acts as food crop indirectly. The sale of potato generated about Nu. 797 million in 2016 and is the highest revenue-earner amongst the agricultural commodities in Bhutan (Department of Agriculture 2017) and there is further potential to increase the revenue. Average yield and production of potato from 2012 to 2016 was 9.64 ton/ha and 51,034.4 ton, respectively (Table 1). The potato yield slightly increased from 2012 to 2014 but it dropped in the following years (Table 1). Besides stagnation of yield, the crop productivity in Bhutan is one of the lowest in the South Asian region as yields in Bangladesh, India and Nepal were 19.4, 22.9 and 13.7 ton/ha, respectively, in 2014 (FAO, 2014).

Table 1. Cultivated area, yield and production for 2012 to 2016

Year	Cultivated area (ha)	Yield (ton/ha)	Production (ton)	Source*
2012	5,078.11	8.47	43,000	Agriculture Statistics 2012
2013	5,419.26	9.30	50,390	Agriculture Statistics 2013
2014	5,174.02	10.36	53,612	Agriculture Statistics 2014
2015	4,859.57	10.16	49,358	Agriculture Statistics 2015
2016	5,923.51	9.93	58,822	Agriculture Statistics 2016
Average	5290.89	9.64	51,036.4	

* Annual publications (2013 to 2017) of the Department of Agriculture, Ministry of Agriculture and Forests

The stagnation of potato productivity of potato in Bhutan is due to lack of diversity of varieties and degeneration of potato seed quality. Hence, there is a need to carry out variety development research to increase the diversity of varieties for the growers for increased production. This is because through improved management and better germplasm the productivity can be enhanced as our current productivity (Department of Agriculture 2017) is less than half of the productivity in India in 2014 (FAO 2014). Therefore, the main objectives of this study were to evaluate different potato genotypes that were received from the International Potato Centre, Lima to identify the most promising varieties through participatory varietal selection (PVS) and conduct demonstration trials in farmer's field to showcase the yield potentials of these new varieties for better adoption. Since farmers are the ultimate users of the potato varieties participatory research methodology is adopted to

holistically include social preferences along with scientific traits like yield potentials, disease resistance, nutrient content and so on. Due to participatory nature of conducting research, farmers are likely to adopt new varieties after the formal release. This study is anticipated to address the problem of yield stagnation and contribute to increasing potato production in the country.

2. Materials and methods

In 2015, advanced evaluation trials were conducted on-station (mother trial) and on-farm (baby trial) in Choekor block under Bumthang district (2650 m.a.s.l) representing high altitude agroecological zone and in Khangma (2100 m.a.s.l) under Trashigang district representing mid-altitude agroecological zone (Wangckuk et al 2014). The experiments were laid out in a randomized complete block design (RCBD) with three replicates in mother trial whilst baby trial consisted of plantings in three different locations in farmers' field. The advanced evaluation trial was conducted using the CIP originated potato clones of 399053.11, 394034.7, 394611.112, 396034.268, 397196.3, 392797.22 and 303381.30 and Desiree as the local check (control). For both mother and baby trials, identical plot size of 2.8 m^2 (2 m x 1.4 m) was maintained for each treatment and twenty tubers were planted in two rows per treatment. Land was ploughed with power-tillers and ridges were made manually. Potato tubers were planted with a distance of 20 cm between the plants and 70 cm between the rows. The crop was fertilized based on the nutrient recommended rate i.e. 79:89:40 N:P:K kg/ha (NSSC 2013). Farmyard manure was also applied at 12 ton/ha. The crop was grown under rain-fed condition and no plant protection measures were required.

Participatory varietal selection (PVS) workshop was conducted both at flowering and harvesting stages in both the trial locations. However, only the PVS data for harvesting stage in Bumthang is presented here in detail. PVS in Bumthang was conducted on 13th August 2015 and 27 farmers (seven men and 20 women) participated in the PVS workshop. During the PVS exercise, yields were measured and social evaluation (preference voting) was conducted using standard PVS procedures of CIP. The PVS event was organised jointly by the scientists of CIP Regional Office in New Delhi and National Potato Program (NPP). The participants were explained about various exercises involved in the PVS. Gathering and ranking of plant criteria like appearance, crop health at harvesting stage and ranking of preferred clones through casting individual votes. The participants were informed about different CIP clones of potatoes available in Bhutan and how the different genetic material differs in tuber shapes and colour, vegetative characteristics, biotic and abiotic stresses, and nutrient content. They were also explained on how to list and rank preferred vegetative criteria. At the harvesting stage, morphologies like tuber shape, eye depth, skin colour, tuber uniformity, yield and pests and disease tolerance were assessed. Participants' opinions were taken for preferred clone/variety. Each of these criteria was written on the board as the farmers were answering about the preferred characteristics. These listed criteria were ranked as per participants' choice. Each of the above criterions was written on a paper and kept on the table in front of a plastic bottle. The participants ranked the criteria by casting a vote for the three most important criteria based on their preferences. Women and men participants were given 6 bean and maize seeds, respectively to cast their votes i.e. 3 seeds for the first

most important clone, 2 seeds for the second, and 1 seed for the third important clone as per their choice. The same procedure was repeated for all 3 replications of mother trial on-station. Similar voting procedures were used for the three baby (on-farm) trials in the farmers' field. The result of the votes per clone was counted and the clones were ranked based on the number of votes received. Yield and vote data generated were analyzed using Highly Interactive Data Analysis Platform (HIDAP) software developed by CIP (CIP 2017) to assess the farmers' preferences. Microsoft Excel was used to generate graphs and compute standard errors for the research trials.

In order to effectively disseminate information on newly released varieties, demonstration trials in farmer's field is necessary. In this regard, three demonstration trials were conducted at Lobnekha (Chapcha, Chukha), Esu (Haa) and Baylanda (Kazhi, Wangdue) in 2017. The demonstration sites were selected in consultation with respective Dzongkhag and geog staff. Each demonstration was laid out in a selected individual farmer's field. Each demonstration site was provided with 50 kg seed of three varieties, namely, Nasephey Kewa Kaap (NKK), Yusi Maap and Desiree (standard check). The demonstration sites were provide with one set of irrigation equipments (one roll each of HDP pipe and flexible, and one sprinkler) to facilitate irrigation. The trials were established during January and February 2017 and were managed by the farmers with technical backstopping from the Agriculture Extension Supervisor (EAS) and National Potato Program. Field days were conducted during the harvest of potato in July and August 2017. Crop agronomic performance was measured using yield and farmers' feedback on preference which was scientifically assessed using voting method as in the case of mother and baby trials. The results were shared with the participants during the field day at each demonstration site.

3. Results and Discussion

As PVS involves both scientific measurements and social evaluations, it has emerged as the best method to identify farmers' preferred crop varieties and their popularization. PVS helps farmers to get familiar with adoption of new varieties and helps researchers in decision making. Among the seven selection criteria, high yield was identified as the most important criterion with 78 votes (20 males and 58 females' votes) followed by medium and uniform size with 29 votes (Table 2). On the other hand, scab resistant and chipping qualities were the least important criteria with seven votes each.

Table 2. Farmers' criteria of potato genotype selection in Bumthang

Sl/No.	Criteria	Score (Men)	Score (women)	Overall score	Rank
1	High yield	20	58	78	1
2	Oblong shape	7	2	9	5
3	Floury texture	1	10	11	4
4	Medium and uniform size	6	23	29	2
5	High nutrients	4	17	21	3
6	Scab resistant	2	5	7	6
7	Chipping quality	2	5	7	6
	Total	42	120	162	

Analysis of variance of the PVS yield data shows that the genotypes were statistically (P<0.05) different in terms of yield and farmers' preference (Table 3). Potato tuber size distribution of the genotypes for mother trial is presented in Figure 1 and that for baby trial in Figure 2. Results of statistical analysis (Table 3) show that commercial yield (i.e. combination of seed size and table size) of the clones 399053.11, 394611.112 and 392797.22 did not differ significantly (P<0.05) among them. Further, 394034.7, 396034.268 and Desiree were also statistically not different (P<0.05). However, the yields of 397196.3 and 392797.22 clones were significantly higher (P<0.05) than Desiree in both the mother and baby trials. Similar findings were also found for non-commercial yields that comprise tubers of <30g weight per tuber. Based on preference ranking, 397196.3, 392797.22 and 399053.11 clones received the maximum votes both in mother and baby trials (Figure 3) and this implies that they are the most preferred clones among treatments in the trial. Further, the chi-square analysis on the preference ranking votes (Table 3) indicated that 397196.3, 392797.22 and 399053.11 outstood from among other clones in the mother trial but were not significantly different (P<0.05) from Desiree in the baby trial.

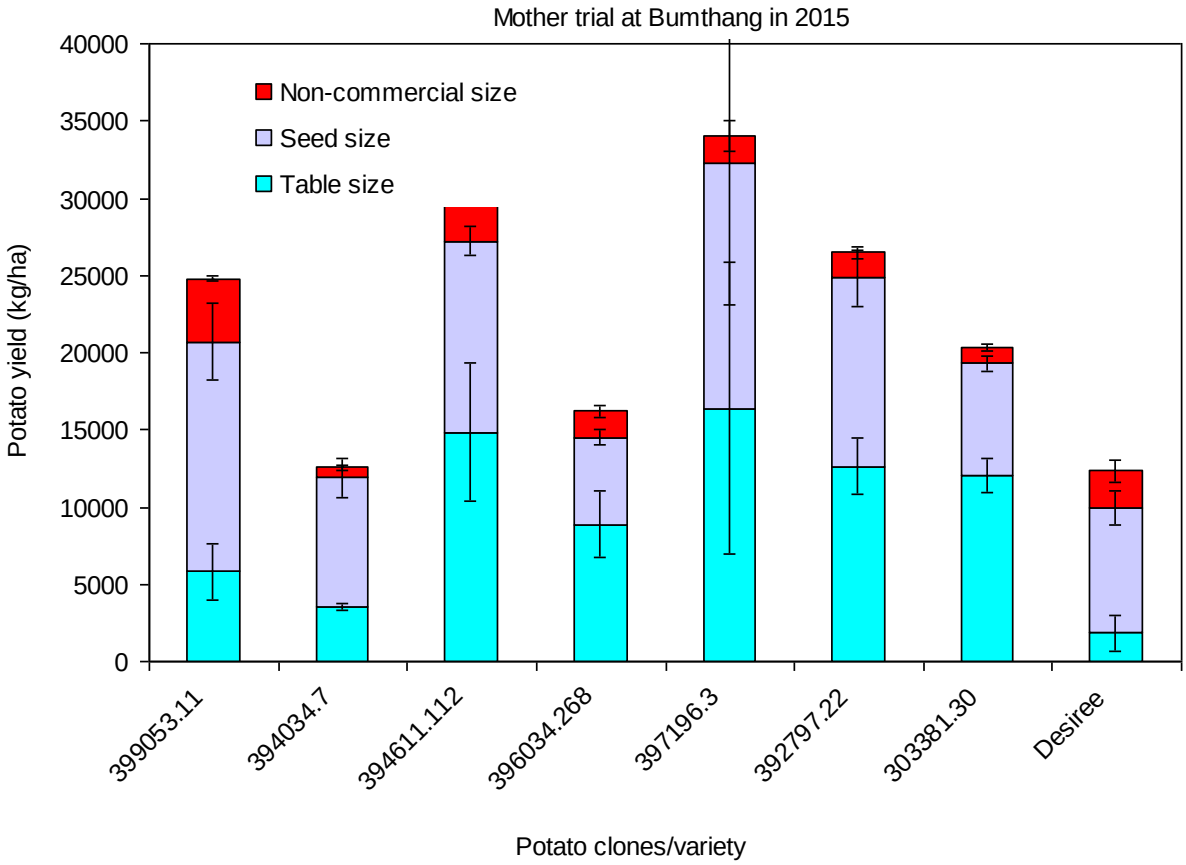

Figure 1. Yields of potato clones/variety from the mother trial at Bumthang. Values are means of three replicates and error bars show standard errors of the means each tuber size. Table size = >65g/tuber' Seed size = 30-65 g/tuber and non-commercial size = <30g/tuber

On an average, the new potato clones yielded 23.4 ton/ha (ranges 12.6 to 34.0 ton/ha) and Desiree, the local variety, yielded 12.3 ton/ha in the mother trial. However in the baby trial, the average yield for the new clones and Desiree was 21.4 ton/ha (ranges 5 to 37.3 ton/ha)

and 21.5 ton/ha, respectively. Among the clones, 397196.3 performed the best in the mother plot whilst 392797.22 did best in the baby trial. In both the trials, least yielding clone was 394034.7 with yield lower than that of Desiree. In terms of social assessment, the most preferred clone was 397193.3 and least preferred was 394034.7 in the mother trial. However, when the clones were assessed against yield (Figures 1 and 2) in combination with preference ranking (Figure 3), 397193.3 and 392797.22 were better clones. The two clones had significantly high (P<0.05) yield and were the most preferred ones than Desiree (control) in both the mother and the baby plots. For instance, the average yield of 392797.22 was 88% (15 ton) higher and received more than 8 times preference votes than Desiree. Similar results were also found at Khangma. Such similar pattern was also observed at both Bumthang and Khangma in 2014.

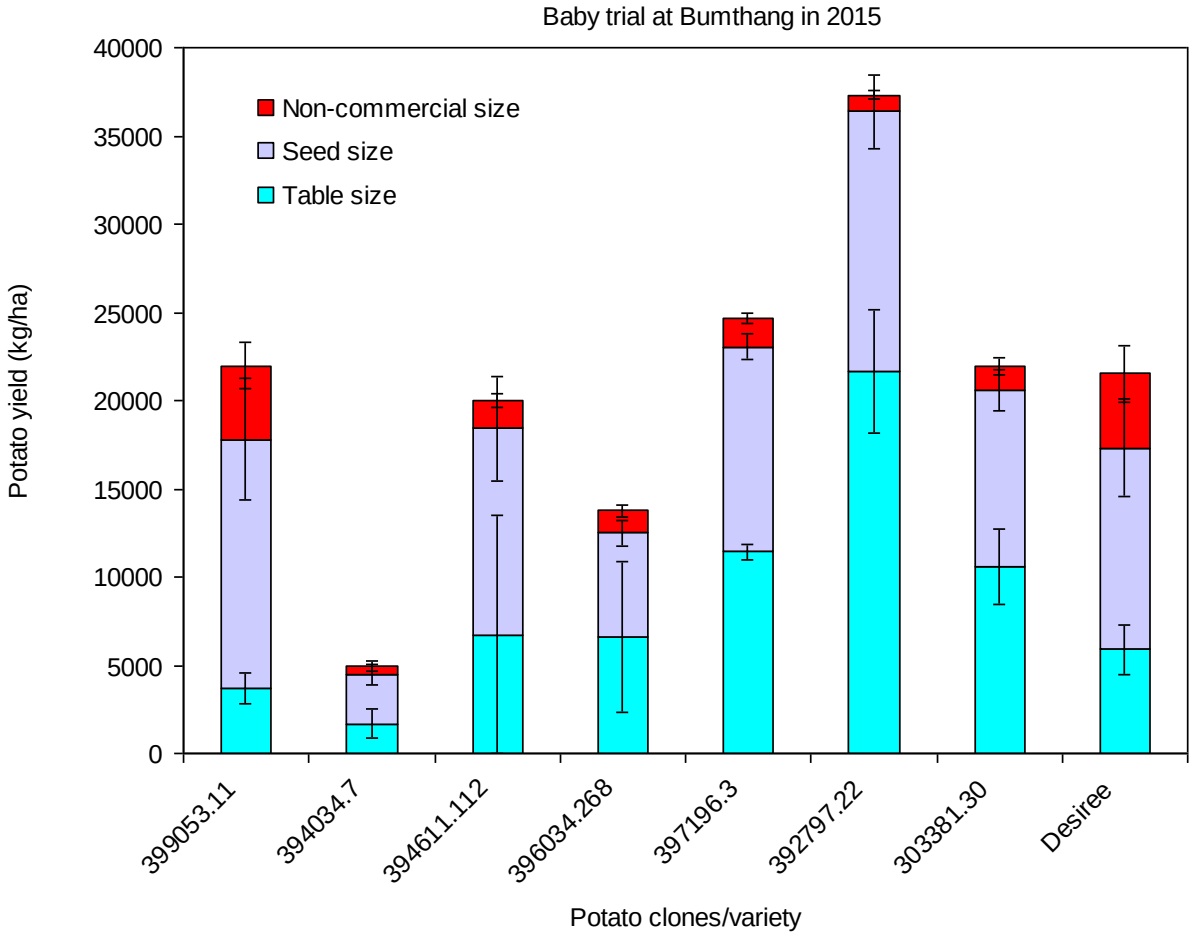

Figure 2. Yields of potato clones/variety from the baby trial at Bumthang. Values are means of three replicates and error bars show standard errors of the means each tuber size. Table size = >65g/tuber Seed size = 30-65 g/tuber and non-commercial size = <30g/tuber

For potato growers the distribution of potato sizes and uniformity is also important besides high yield (Table 2). This is because they need large tuber size for table purpose or consumption and medium size for seed purpose and to sale as seed to other famers (Roder et al 2008). Though smaller in size, the seed size potato earns better prices than the table size potato (Luthra et al 2006) since seed potato is in high demand for planting. From looking at

the distribution of sizes, 399053.11 and Desiree have larger proportion of non-commercial tuber sizes (Figures 1 and 2). The least proportion of non-commercial tubers is found in 394034.7 and 392797.22 in (Figures 1 and 2) which is interest to the growers as the lowest proportion of the total productivity can be non-commercial in value. Based on synthesis of research results, a relatively high yielding (Figures 1 and 2) and moderately preferred (Figure) 392797.22 (red-skinned) was selected for release to farming community. This was selected because it is red-skinned (Bhutanese farmers prefer for the red skinned potato (Roder et al 2008), its observed moderate resistance to a common problem of late blight and its micro-nutrient dense characteristics. It is difficult have all required traits in the same clone and choice of 392797.22 was based on critical analysis of aspects of our potato industry including consumer health. Further, yields of 399053.11, 394611.112, 397196.3 and 392797.22 are comparable to that average yields in neighbouring countries (Bangladesh - 19.4, India -22.9 and Nepal -13.7 ton/ha) (FAO 2014) and are better yielding than our national averages in the recent times (Table 1). In the basic terms, it means that get better yields can be achieved if some of these clones grown on a commercial scale. In other words, better yields can be achieved if some of these clones are grown on a commercial scale.

Based on this study in two locations for two years, clone 392797.22 was proposed for release and was released as a new variety, called Yusi Maap, in 2017. The new variety is expected to address the yield stagnation issue and provide an alternate variety to red-skinned variety to the growers and consumers. Yusi Maap is moderately resistant to late blight which is a major plant protection issue in Bhutan as the other varieties grown in Bhutan are susceptible to late blight except Nasephey Kewa Kaap. According to the International Potato Centre, Lima, it has high Iron (> 18.45 mg/kg dry weight basis), high Zinc (> 16.5 mg/kg dry weight basis), and moderate vitamin C (59.85 to 89.7 mg/100g dry weight basis) content. Hence, the nutrient-dense trait of this variety is expected to address malnutrition like anaemia in children and women, whose diet consists of some potatoes in one form or the other. This is the first micro-nutrient dense variety released in Bhutan and is expected to revolutionize consumption pattern because of the stereotype thinking that potato can only provide carbohydrates. However, the major challenge now is to produced enough seeds (seed rate 2 ton/ha) to meet the requirement of the growers.

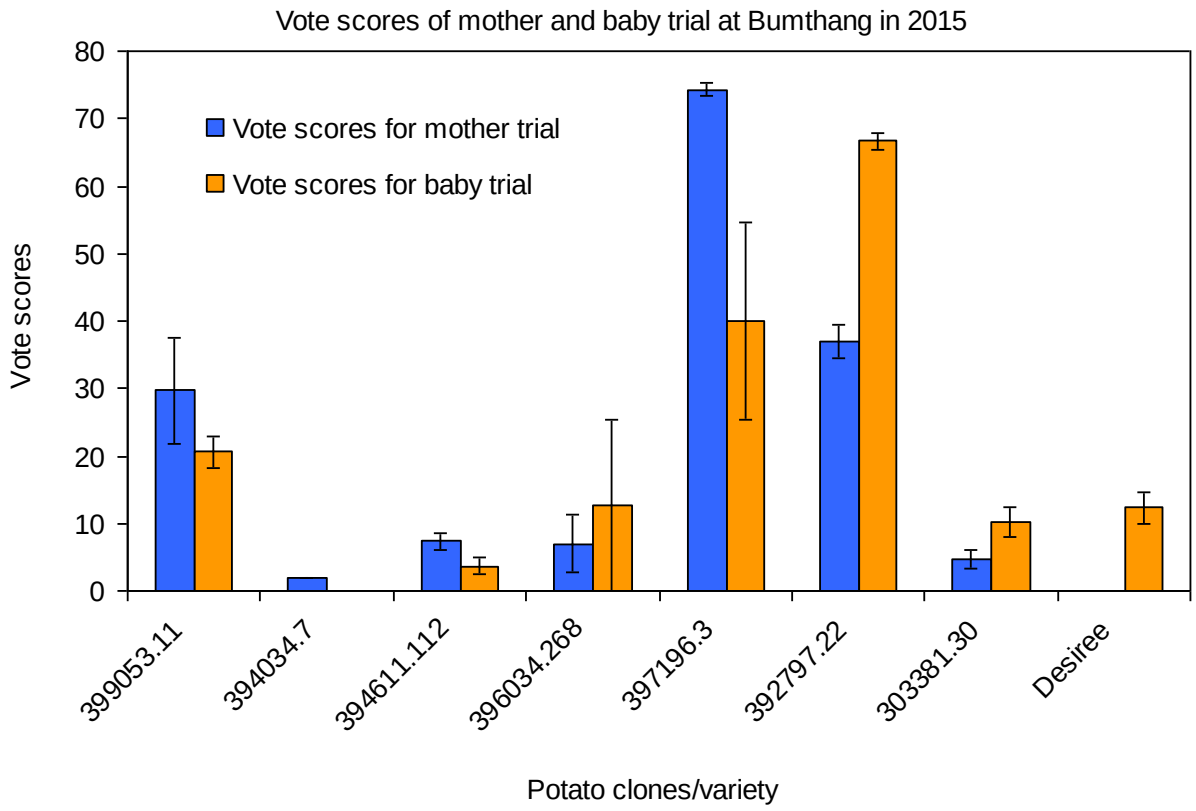

Figure 3. Farmers' preference vote scores of potato clones/variety for the mother and baby trial at Bumthang. Values are means of three replicates and error bars show standard errors of the means

Table 3. Summarized results of the least significant difference (LSD) method for yield comparisons amongst the clones/variety and chi-square analysis for the preference votes

Sl.No.	Clones/variety	Marketable yield in mother plot		Chi-square analysis of mother plot	
		Mean marketable yield (kg/ha)	Multiple comparison using LSD	Mean votes scored (No.)	Multiple comparison
1	399053.11	20,714	bcd	29.67	a
2	394034.7	11,905	e	2.00	cd
3	394611.112	27,202	ab	7.33	b
4	396034.268	14,524	de	7.00	bc
5	397196.3	32,262	a	74.33	a
6	392797.22	24,821	bc	37.00	a
7	303381.30	19,286	a	4.67	bc
8	Desiree	9,940	e	0.00	d
		Non-marketable yield in mother plot		Chi-square analysis of baby plot	
1	399053.11	4,048	a	20.67	ab
2	394034.7	655	c	0.00	d
3	394611.112	2,619	b	3.67	cd
4	396034.268	1,667	bc	12.67	cd
5	397196.3	1,726	bc	40.00	ab
6	392797.22	1,667	bc	66.67	ab
7	303381.30	1,012	c	10.22	cd
8	Desiree	2,381	b	12.33	bc

Values are means of three replicates in both mother and baby trials. Different letters indicate significant differences between the clones/variety at $P<0.05$.

3.1. Experiences from demonstration of new potato varieties

In order transfer the technology generated by the National Potato Program to farming community and to encourage farmers to grow for new varieties, a number of demonstration trials for new potato varieties (i.e. Nasephey Kewa Kaap [NKK] and Yusi Maap) was conducted in three potato growing Dzongkhags of Chukha, Haa and Wangdue (Table 4). The results of the demonstration trials show that both NKK and Yusi Maap had much better yield than the currently popular variety Desiree. Highest yield of NKK and Yusi Maap was observed in Chukkha with 37.1 and 35.5 ton/ha, respectively (Table 4). Yusi Maap was the top yielder in Chukha and Haa but NKK performed better in Wangdue. As expected, Desiree yielded the least among the three varieties in all the three locations and this could be attributed to decline in its seed quality. Analysis on the farmers' preference ranking showed that Yusi Maap was most preferred in all the three locations probably due to its red coloured skin (Roder et al 2008) and better crop productivity (Table 4). Preference for red skin by farmers can be further substantiated as Desiree, a low yielding variety, received the second

highest votes in Chukha and Haa based on its skin colour. The average yield of Yusi Maap was quite comparable to that of the average yield in the neighbouring countries (Bangladesh - 19.4, India-22.9 and Nepal-13.7 ton/ha (FAO, 2014). Unlike Yusi Maap (21.8-37.1 ton/ha), NKK showed larger yield variations (15.5-35.5 ton/ha) among the demonstration sites. On the whole, the study results indicate that new variety such as Yusi Maap has a great potential to increase potato production in the country. It is also highly likely that growers will go for it due to its red skin for better marketing preferences. On the contrary, white skinned potatoes are not as popular as their counterparts and therefore, future research efforts should be focused on releasing more red-skinned potato varieties.

Table 4. Summary of potato yields and farmers' preference ranking in three Dzongkhags: Results of technology transfer through demonstrations in 2017

Location	Genotype identification	Year of release	Variety name	Mean yield (ton/ha), n=3	SE of yield	Votes count (women)	Votes count (men)	Total votes	Rank
Lobnekha, Chapcha, Chukha	CIP393077.159	2014	NKK	**35.5**	2.53	18	19	37	**3rd**
	CIP392797.22	2017	Yusi Maap	**37.1**	2.58	43	41	84	**1st**
	CIP800048	1988	Desiree	**20.8**	1.35	23	24	47	**2nd**
Esu, Haa	CIP393077.159	2014	NKK	**15.5**	2.31	11	12	23	**3rd**
	CIP392797.22	2017	Yusi Maap	**23.4**	3.12	24	23	47	**1st**
	CIP800048	1988	Desiree	**13.7**	1.74	13	19	32	**2nd**
Baylanda Kazhi,	CIP393077.159	2014	NKK	**26.9**	0.99	57	36	93	**2nd**
	CIP392797.22	2017	Yusi Maap	**21.8**	4.42	81	43	124	**1st**
	CIP800048	1988	Desiree	**5.6**	0.87	30	17	47	**3rd**

NKK=Nasephey Kewa Kaap, SE = standard errors

4. Conclusions

Participatory varietal selection involves both scientific measurements and social evaluations; hence it has emerged as the best method to identify farmers' preferred crop varieties and their popularization. PVS helps farmers to get familiar with adoption of new varieties and helps researchers in decision making. Analysis on the farmers' preference ranking showed that 392797.22 (Yusi Maap) was the one of the preferred clone due to its high yield potential, red-coloured skin and it was also found be one of the better yielder. However, other genotypes of 399053.11, 394611.112, 397196.3 and 392797.22 are still better than the local varieties. Yusi Maap was released as an official variety because of its yield potential, late blight resistance (moderate) and micro-nutrient content besides farmers' preference for it. As such, there is a good scope to increase potato production in the country if these new varieties can be grown at large scale. In summary, the study results indicate that new variety such as Yusi Maap has a great potential to increase potato production in the country. It is also highly likely that

growers will go for it due to its red skin for better marketing preferences and due to its high micro-nutrient content for higher consumption. Contrastingly, white skinned varieties are not as popular as their counterparts and therefore, future research efforts should be focused on releasing more red-skinned potato varieties. The study has demonstrated farmers' preference for the new varieties and thus more resources should be invested to produce sufficient seeds of these promising new varieties. If the technology is disseminated and adopted well, the impact of the study could be realized in future as more income to the farmers and better health to the consumers.

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