RESEARCH ARTICLE

POST-HARVEST LOSSES OF POTATO GENOTYPES AT FARMERS' STORAGE CONDITIONS

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ABSTRACT

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Potato is one of the major crops of Nepal and postharvest loss is one of the major problems in the potato value chain system. Therefore, this study was conducted with the objective of assessing post-harvest losses of potato under farmers' storage conditions. Potato tubers of six potato genotypes (three released varieties viz. 'Jankdev', 'Khumal Upahar' and 'Khumal Vikash' and three pipeline genotypes viz. 'CIP 393073.179', 'CIP 395112.32' and 'Techno 304351.109') were evaluated in randomized complete block design with three replications under four different farmers' storage conditions at Panauti-8, Kavrepalanchok district of Nepal from May to August 2019. The tubers were cured after harvesting for two weeks in a shade, thereafter they were stored for 80 days. Data were recorded on 20, 40, 60, and 80 days of storage. The results showed that at 80 days of storage, the lowest weight loss (5.51%) was found in Techno 304151.109 followed by CIP 393073.179 (6.68%). Potato tuber moth infestation was minimum in CIP 393073.179 (1.15) followed by Techno 304151.109 (1.25). The days to sprouting was the highest in CIP 393073.179 (69.25) followed by Techno 304151.109 (68.75). No shrinkage was observed in CIP 393073.179 and Techno 304151.109 till 60 days of storage. Loss due to rotting was not observed in these genotypes. Therefore potato genotypes CIP 393073.179 and Techno 304351.109 were promising for their storability in farm conditions; which can be recommended for commercial production in the mid-hill environment of Nepal.

KEYWORDS

Potato, potato tuber moth, weight loss, shrinkage, sprouting, storability.

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is emerging cash generating crop in Nepal. A recent increase in its use in several Nepalese recipes has made it a versatile vegetable crop throughout the country, while it is a staple food for residents of high hills and mountains. In Nepal, the area under potato was reported 195,173 ha and total production 2,881,829 tons with average productivity of 14.7 t/ha which is lower than the neighboring countries (MoALD, 2019). In Bangladesh, China, India, Netherlands and USA, potato yields were 20.4, 18.8, 22.6, 36.6 and 49.8 mt/ha respectively in the year 2018 (FAOSTAT, 2020). It occupies the fifth position in area coverage, second in total production, and first in productivity among the food crops grown in Nepal. Out of the total area under potato, province 1, province 2, Bagmati, Gandaki, Province 5, Karnali and Sudur Paschim occupied 32.4%, 13.0%, 21.7%, 8.1%, 11.0%, 6.0% and 7.7%, respectively (MoALD, 2019). The total production of potato could not be utilized due to losses during handling and storage at farm level.

Post-harvest loss of perishable commodities including potato is one of the major value chain problems in many countries including Nepal. A large % of post-harvest loss of perishable commodities is estimated in SAARC countries like Sri Lanka (30-60 %), Maldives (30-40%), and Nepal (20-

30%, sometimes up to 50%) (Karki, 2002; Rasheed and Shareef, 2002; Wijeratnam, 2002). Post-harvest potato loss was estimated at 24% in India, 20% in Bangladesh, and 25% in Nepal (Karki, 2002; Prasad et al., 1989; Satter et al., 2002). It was observed that about 6% loss was during post-harvest handling and marketing in Chattisgarh India (Raghuvanshi et al., 2018). About 40% of this loss was estimated in potato (Khairegoli, 1998). Significant post-harvest loss in potato was identified as one of the major causes of low total yield in potato (NPRP, 2015). In this context, farmers need to use technologies to reduce post-harvest losses. Disciplines of NARC such as National Potato Research Programme and Entomology Division have developed some technologies for reducing post-harvest losses; however, their promotion to farming communities is inadequate (Gautam et al., 2016; Giri et al., 2016).

The main causes of post-harvest losses were sprouting during room storage, the infestation of potato tuber moth (PTM), weight loss due to several causes and limited knowledge and awareness of post-harvest technologies in the farming communities (NPRP, 2018). One of the major biotic factors such as potato tuber moth alone can cause 100% infestation in untreated potato in local unrefrigerated stores (CIP, 1988; Joshi, 1989; Aryal and Jung, 2015). The potato growers of the pockets of the super zone of potato such as Panauti, Nala, Panchkhal, and Kusadevi areas of Kavre

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districts were also facing the problem of considerable loss of potato under ordinary storage condition (Upadhyay et al., 2016). The main causes of post-harvest loss in these areas were varieties with short post-harvest life, early sprouting in ordinary storage; tuber rot, shrinkage, and infestation of potato tuber moth (Upadhyay et al., 2016). Farmers are lack of technologies on post-harvest value addition of potato and post-harvest losses reduction due to the biotic and abiotic factors. The problem of post-harvest losses could be solved through the application of low-cost technologies such as the utilization of varieties with long post-harvest shelf life. Therefore, this study has been undertaken to estimate the post-harvest losses of potato under farmers' storage conditions. The present study explains how the potato genotypes vary in their performance in terms of storage capabilities and response to potato tuber moth while they were stored in ordinary storage condition.

2. MATERIALS AND METHODS

2.1 Study area description

An experiment was conducted by National Potato Research Program (NPRP) at Panauti Municipality 8, Panauti in Kavre Palanchok district. Panauti Municipality is situated at 27° 34' 58" N and 85° 30' 34" E with the altitude of 1232-1500 meters above mean sea level while experimental site was in 1330 masl. Its climate is a subtropical type where three crops

of potatoes can be grown in a year. However, September-to November and February-March are main planting seasons.

2.2 Potato genotypes

This experiment was conducted to identify appropriate potato genotype with long post-harvest shelf-life under ordinary storage conditions. The experimental design was a randomized complete block with 3 replications in 4 farmers' storage conditions. The experiment utilized the room floors of a farmer's house as storage. The experiment consisted of 6 treatments (potato genotypes) among them 3 were released varieties ('Janakdev', 'Khumal Upahar' and 'Khumal Vikash') and 3 promising lines such as CIP 393073.179, 395112.32 and Techno 304351.109 (Table 1a and Table 1b). The source of the majority of the genotypes was the International Potato Center (CIP). Post-harvest shelf-life of these genotypes was not studied in Panauti environment previously even though this site is under the super zone of potato of the Prime Minister Agricultural Modernization Project.

The genotypes varied in their source, tuber color, flesh color, tuber shape, eye depth, maturity, and yield (Table 1a and Table 1b). The genotypes CIP 393073.179, Janakdev, Khumal Vikash and Techno 304051.109 were red in color while CIP 395112.32 and Khumal Upahar were white. The flesh color of CIP 393173.179, Janakdev and Khumal Upahar was yellow while Khumal Vikash, Techno 304051.109 and CIP 95112.32 had creamy flesh. The tuber shape was oval in CIP 393073.179, Long in Janakdev.

Table 1a: Potato genotypes used as the treatments for the experiment

Genotypes	Original Name	Source	Status
CIP 393073.179 ³	CIP 393073.179	CIP	Pipeline
Janakdev ¹	Atzimba x Desiree (Urgenta x Depesche)	CIP	Released
Khumal Upahar ¹	CIP 389746.2	CIP	Released
Khumal Vikash ²	Desiree (Urgenta x Depesche) X LBr 40	Nepal	Released
CIP 395112.32 ³	CIP 395112.32	CIP	Pipeline
Tech 304351.109 ⁴	Techni-tuber series 304351.109	CIP	Pipeline

¹Upadhyay, 2017; ²Upadhyay 2018; ³CIP 2014; ⁴NPRP 2017

Table 1b: Features of potato genotypes used as the treatments for the experiment

Genotype	Skin color	Flesh color	Shape	Eye depth	Maturity days	Yield t/ha ⁴	Special features
CIP 393073.179 ³	Light Red	Yellow	Oval	Shallow	110-130	17.6	High vit. C, Zn and Fe ¹
Janakdev ⁶	Red	Yellow	Long	Medium	110-130	25.0	Late blight resistant
Khumal Vikash ²	Red	Cream	Round to oval	Shallow	90-110	25.4	Chips purpose, late blight resistant
Khumal Upahar ⁶	White with red eyes	Yellow	Round	Deep	110-130	24.8	Late blight resistant
Techno 304051.109 ⁵	Red	Cream	Round	Medium	90-110	27.48	Heat tolerant
CIP 395112.32 ³	White	Cream	Oval	Medium	90-110	24.4	High Vit C ¹

¹CIP, 2014; ²Upadhyay, 2018; ³Luitel et al., 2017; ⁴NPRP 2016, 2017, 2018; ⁵NPRP 2018; ⁶Upadhyay, 2017

Potato genotypes were harvested in the second week of May 2019 after they reached their full harvesting maturity. Storage experiment was conducted on the third week of May 2019 and continued to the second week of August 2019 (80 days). Curing was done under shade house for 2 weeks and allowed for periderm formation. Twenty tubers (50-100 g size) of each genotype were selected for the experiment. These tubers were spread on the experimental floor randomly and genotypes were separated with wooden sticks. Nutrient-rich genotypes CIP 393073.179 and CIP 395112.32 were included to determine their potentiality of storage (Luitel et al., 2017).

2.3 Temperature and relative humidity

Daily maximum and minimum temperatures were recorded with the maximum and minimum thermometer while dry and wet bulb thermometer readings were used to calculate the relative humidity. The thermometer records were taken at 6 am every day. Morphological data and yield were taken from a previous season's performance of the genotypes. Data were recorded on 20, 40, 60, and 80 days of storage.

2.4 Data recording and analysis

Observations on average weight loss, infestation by tuber moth, days to sprouting, shrinkage behavior, and damage due to rotting were recorded. Weight loss was calculated by deducting periodic weights of tubers from the initial weight at the time of storage and was expressed in %. Tubers infected with potato tuber moth (*Phthorimaea operculella*) also called as PTM were recorded with the number of infested eyes in the tuber. The number of sprouted tubers was recorded at the end of the experiment. Shrinkage behavior was recorded when tubers of a genotype started shrinking during the recording interval. The number of rotted tubers was recorded at the time of each recording which was separated and disposed. The sum of the number of rotted tubers was added at the end of the experiment and total rotted tubers were presented.

Data were managed in a spreadsheet and analyzed with Genstat version 18 (VSN International, 2015) software for windows. Analysis of variance was used to determine statistically significant differences between means. Post hoc analysis was done by Duncan's Multiple Range Test. Least

significant differences were determined for all significant data and the correlation coefficient was calculated to find out the relationship between the number of eyes per tuber and the number of infested eyes per tuber by PTM.

3. RESULTS AND DISCUSSION

3.1 Temperature and relative humidity of the site

The weather of Panauti was summer during the experimental period. As a subtropical climate, temperatures were in the range; however, they were higher than the requirement of potato storage. For potato storage, ideal room temperatures should be between 42- and 50-degree Fahrenheit (5.5-10 degree Celcius) while the maximum and minimum temperatures of the Panauti site were beyond the ranges (Woodwell et al., 2009). Maximum temperatures of Panauti ranged 19.6-29.6 degrees Celcius while minimum temperatures varied from 11.4 to 16.9 degrees Celcius (Table 2). Similarly, Relative humidity ranged from 72% to 96%. Relative humidity figures were lower in the initial 4 weeks than the latter indicating the dry spell during May in the pre-monsoon period. In latter weeks, the humidity was within the range of requirements of potato. The ideal relative humidity for storing potato is 90-95% (Woodwell et al., 2009).

Table 2. Temperature and relative humidity of the experimental site

Week	Temperatures (degree Celcius)		Relative humidity (%)
	Maximum	Minimum	
1	21.6	14.9	77
2	29.6	16.2	72
3	25.9	13.9	72
4	28.4	13.8	75
5	27.9	16.9	91
6	19.6	11.4	95
7	22.9	13.6	78
8	23.5	13.9	86
9	24.6	14.9	91
10	24.4	13.2	91
11	24.9	11.7	90
12	24.6	13.4	96
13	23.4	13.1	96
14	23.4	13.9	86
15	22.6	15.1	82
16	20.0	15.8	90

3.2 Storage capabilities

3.2.1 Weight loss

Significant differences were observed for weight loss between the genotypes when they were stored for 40, 60, and 80 days of storage ($P < 0.05$) while no differences were recorded on 20 days of storage. In 20 days, the % of weight loss ranged from 1.6 (CIP 393073.179) to 3.2 (CIP 395112.32) (Figure 1). In 40 days, the loss was the highest (8.14%) in CIP 395112.32 and the lowest (3.3%) in Techno 304351.109 (Table 3). In 60 days, the highest weight loss (9.88%) was observed in CIP 395112.32 and the lowest (4.31%) in Techno 304351.109 followed by CIP 393073.179 (5.55%). In 80 days, CIP 395112.32 had the highest (11.82%) weight loss followed by Khumal Vikash (10.47%) while it was the lowest (5.51%) in Techno 304151.109 followed by CIP 393073.179 (6.68). The extent of weight loss during storage relies on genotype which was also linked to the present study (Patel et al., 2002). A group researcher reported that late maturing potato varieties had good storability which was also true in our experiment (Pandey et al., 2000). Another study showed that the heat-tolerant hybrids had good storability (Naidu and Nandekar, 2005). In our experiment, Techno 304351.109 was defined as heat tolerant and showed less weight loss. An experiment conducted in Modipuram included three cultivars stored at room temperature (24 – 36 degree Celsius) from mid-March to mid-May in which the weight loss in K. Surya was lower (9.1%) compared to controls varieties K. Bahar and K. Jyoti (12 - 13%) (Ezekiel et al., 2004).

According to a study, varieties were characterized by different weight loss behavior that agreed to the results of the present study (Hardenburg, 1949). The author further explained that approximately 60 % difference

in weight loss was occurred from transpiration in tested varieties Sebago and Houma, depending upon the prominent lenticels on tubers. Differences for weight loss in 7 potato varieties and in storage temperatures were determined in an experiment conducted in which weight loss was 26.4% at 10-degree Celcius due to excessive sprout growth; with minimum weight loss in potatoes stored at 4-degree Celcius and maximum in those stored at 10 degrees Celcius (Ezekiel et al., 2007). Our results were in line with these outcomes. In a previous experiment conducted at NPRP, at 120 days of ambient storage significantly less weight loss was recorded in genotypes Yagana (12.3%) and L-235.4 (14.7%) followed by K. Jyoti (16.1%) and Khumal Set-1 (16.5%) (Gautam et al., 2016). A group researcher reported that variation was observed in varieties in storage behaviors or shelf life of potato (Kumal et al., 2001). The storability evaluation of potato varieties at room temperature for 105 days showed that K. Chipsona-2 recorded higher weight loss than K. Pushkar, K. Surya, and K. Chipsona-1 (Mehta et al., 2006). These all reports indicate that the varieties respond differently for their weight loss to the storage environments.

Figure 1: Weight loss of potato genotypes under ordinary storage condition in Panauti, Nepal

Table 3: Group comparison genotypes for their weight loss %

Genotypes	40 days	60 days	80 days
CIP 393073.179	4.32 ± 0.75 ab	5.55 ± 0.70 a	6.68 ± 0.89 ab
Janakdev	4.85 ± 0.162 ab	6.39 ± 1.42 a	7.93 ± 1.12 b
Khumal Vikash	6.36 ± 0.93 bc	8.69 ± 0.85 b	10.47 ± 0.48 c
Khumal Upahar	4.23 ± 0.16 ab	6.10 ± 0.98 a	7.62 ± 0.62 b
Techno 304351.109	3.33 ± 0.68 a	4.31 ± 0.64 a	5.51 ± 0.40 a
CIP 395112.32	8.13 ± 0.98 c	9.88 ± 1.16 b	11.82 ± 1.36 c

The ± values represent standard error of the mean. The values followed by same letters are not significantly different by DMRT or LSD? at 0.05 or 0.01

3.2.2 Damage by potato tuber moth

Number of eyes per tuber (F probability = 0.008, CV% = 14.2 and LSD = 1.06) and number of infested eyes per tuber (F probability = 0.042, CV% = 12.6 and LSD = 1.191) were significantly different between genotypes ($\alpha = 0.05$). Average number of eyes per tuber ranged from 5.2 (CIP 395112.32) to 7.1 (CIP 393073.179) (Figure 2). The potato tuber moth infested the largest number of eyes (5.95) per tuber in CIP 393073.179 while the Khumal Vikash the smallest (3.95). The difference between the number of eyes and infested eyes was greater (1.6) in Khumal Vikash while it was the least (1.15) in CIP 393073.179. It was observed that the tubers of CIP 393073.179, Khumal Upahar, and Techno 304351.109 were infested by the pest on the surface only. We cut the tubers to observe the mining trend of the pest into the tuber. It showed a large part of the flesh of these genotypes was edible after peeling. The larvae of potato tuber moth had mined into the tubers of CIP 395112.32, Janakdev, and Khumal Vikash till the time of last recording (80 days of storage). The results indicated that the pest infested the tubers of CIP 393073.179, Khumal Upahar, and Techno 304351.109, and either it did not prefer the taste of the flesh or repelled by the tubers smell. The correlation coefficient between the number of eyes and number of infected eyes showed a strong relationship between these two parameters in Janakdev, Khumal Upahar and CIP 395112.32 ($r = >0.5$) whereas the relationship was weak ($r = <0.5$) in CIP 393073.179, Techno 304351.109, and Khumal Vikash (Table 4). The

P values for the correlation coefficient of each genotype were not significant statistically at $\alpha = 0.05$; indicating that there was no significant increase in the infested number of eyes when the number of eyes increased in the tubers (Table 4). However, the experiment P value was significant for the correlation coefficient of these parameters.

Potato varieties may be resistant, susceptible, moderately susceptible, or slightly susceptible to the feeding preferences of the pest which was also observed in the present study. Larval penetrations into the tuber differ in varieties and related to the peel of the tuber which may act as a barrier to the first instar larvae establishment (Fenemore, 1980; Sharaby et al., 2014). We found that the peel of less infested genotypes was damaged but penetration was not extended to the flesh. Eyes number were related to the vulnerability of the tubers towards PTM, Periderm thickness affected neonate penetration and thinner periderm around the eyes increased infestation (Malakar-Kuenen and Tengey) and total protein content favors the growth while digestible carbohydrates negatively related to the PTM growth (Das et al., 1993b; Das et al., 1993a). Another view was the variation between potato varieties may be attributed to different levels of sugar or glycoalkaloid and amino acid contents (Yathom, 1968). The role of any chemicals presents in tuber flesh to repel or distract the potato tuber moth should be the matter of further study. The glycoalkaloids, amino acids and digestible carbohydrate should be determined in the tested genotypes; however, they were not tested in the present study. The mechanism of resistance of varieties to potato tuber moth was most probably antibiosis (Ojero and Mueke, 1985).

Figure 2: Mean Infestation pattern of potato genotypes by potato tuber moth. Bar represent $\pm$ SE

Table 4: Correlation between number of eyes and number of infested eyes due to PTM

Genotypes	Correlation coefficient	p value
CIP 393073.179	0.16	0.838
Janakdev	0.70	0.296
Khumal Vikash	0.03	0.969
Khumal Upahar	0.56	0.436
Techno 304351.109	0.25	0.753
CIP 395112.32	0.82	0.183
Experiment	0.52	0.009

3.2.3 Days to sprouting

There were significant differences between potato genotypes in days to sprouting ($P < 0.05$). Early sprouting (55.2 and 55.5 days after storage) was observed in the genotypes CIP 395112.32 and Janakdev, respectively while it was late (69.2 and 68.7 days after storage) in CIP 393073.179 and Techno 304051.109 (Figure 3). Sprouting did not occur in all genotypes until 40 days of storage. The results indicated that all genotypes could be stored in ordinary room storage for 40 days without any treatment against sprouting. It was also implied that the dormancy of all tested genotypes was at least 40 days of storage. According to a study, Varieties are characterized by different sprouting behavior which agreed to the results of the present study (Hardenburg, 1949). We found differences in sprouting due to the effect of genotype type but reports explained that it was a complex process in which including genetic material, stage of tuber, environment, management conditions, temperature, humidity, water supply, photoperiod, etc. play a vital role (Mani and Hannachi, 2015). Sprouting differs among cultivars which was agreed to the present study results (Hay and Porter, 2006; Carli et al., 2010). Some researchers found that variety 'Desiree' sprouted at sequential storage at 40C for 2 weeks

following 20 degrees Celsius for 3 weeks (Struik, 2006; Mani and Hannachi, 2015).

Figure 3: Days to sprouting of potato genotypes. Bars represent $\pm$ SE

3.2.4 Shrinkage behavior

No shrinkage was observed in all genotypes till 60 days of storage. Thereafter, the genotype CIP 395112.32 started shrinking on 65 days of storage, while all genotypes were partially shrunk on 80 days of storage. Till 80 days of storage, all genotypes were sprouted breaking their dormancy. The shrinkage could be due to loss of moisture through transpiration. The transpiration should also be related to the relative humidity lower than 90% during the early storage period and temperatures higher than 10 degrees Celsius throughout the experimental period (Table 2). The genotype started early shrinkage had also greater weight loss % (Figure 1), damage by potato tuber moth, and sprouting (Figure 3). Therefore, the shrinkage behavior was obvious in the genotype with significant weight loss, sprouting, and damage by the pest. Hardenburg concluded that shrinkage was not significantly different for types of containers but 75% of shrinkage was occurred due to moisture loss and 25% due to sprouting (Hardenburg, 1949). The author further explained that shrinkage due to sprouting was primarily a function of temperature whereas shrinkage due to transpiration was primarily a function of relative humidity. Loss of water and increased heat cause stress in the cellular structure leading to deformations and loss of volume (Ramos et al., 2003; Mayor and Sereno 2004; Frias et al., 2010). According to a study, the shape has an influence on the dimensional shrinkage of potatoes (Mulet et al., 2000). The view is the existence of a strictly linear relationship between shrinkage parameter and moisture content which was disagreed (Hassini et al., 2007; Rahman and Kumar, 2007; Frias et al., 2010). In the present study, the shrinkage was the function of temperature, relative humidity, weight loss, sprouting and damage by potato tuber moth.

3.2.5 Damage due to rotting

There were not significant losses due to rotting during the experimental period. The possible reason behind this could be the environment of the storage rooms. Rotting is mainly caused due to dry rot, soft rot, and other fungal diseases. The host-pathogen interaction is influenced by the environment on either the potato or the pathogen or on both (Masum et al., 2011). In the present experiment, the rooms were well ventilated with sufficient space for spreading on the floor. The genotypes were spread in a single layer without making heaps so that enough aeration between tubers would have provided. Tubers of the genotypes were free from bruising or other damages before storage. They were well dried, free of soil dust, and matured with compact periderm after harvest. In a previous study, 3.95, 0.91, and 0.69% of tubers were infected with soft rot, dry rot and scab diseases (Masum et al., 2011). The authors also indicated that yield losses attributed to dry rot in storage ranged from 6 to 25% in some cases. Similarly, due to bacterial soft rot, the average loss of potato was recorded at about 4.9% at farmer's level in Bangladesh (Rahman et al., 2010). These figures from Bangladesh indicate that the environment of the storage is an important factor for the post-harvest life of potato; which in the present experiment in Panauti was appropriate and less prone to rotting.

4. CONCLUSION

Three released and three pipeline varieties of potato were tested under

the ordinary storage condition of Panauti, Nepal to determine their post-harvest shelf-life. The results of weight loss, damage by tuber moth, days to sprouting, shrinkage behavior and damage due to rotting showed that the genotypes CIP 393073.179 and Techno 304351.109 were promising for their storability in farm condition for 80 days. These two genotypes can be recommended for commercial production in the mid-hill environment of Nepal.

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