EFFECT OF LIFTING TIME AND TUBER SIZE ON AMBIENT STORAGE PERFORMANCE OF POTATO DERIVED FROM TRUE POTATO SEED

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CERTIFICATE

This to certify that the thesis entitled, **“NATURAL STORAGE PERFORMANCE OF POTATO DERIVED FROM TRUE POTATO SEED AS AFFECTED BY LIFTING PERIOD AFTER HAULM KILLING”** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN AGRONOMY** embodies the result of a piece of *bona fide* research work carried out by **Jhuma Shrabanti Nipa** , Registration **No. 09-3705** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly acknowledged by her.

Dated:…….………

Dhaka, Bangladesh.

……………………………

(Dr. Tuhin Suvra Roy)
Professor
Supervisor

Dedicated

To

My Beloved Son

Aryabeer Hriddhi Das

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ABSTRACT

The present study was investigated on the natural storage performance of potato derived from TPS as affected by lifting period after haulm killing and tubers sizes. Five lifting period viz., L_0 (0 days after haulm killing), L_1 (3 days after haulm killing), L_2 (6 days after haulm killing), L_3 (9 days after haulm killing) and L_4 (12 days after haulm killing) and 3 tuber size (small, medium and large) were used individual and combinedly as treatment for this study. The experiment was laid out in a completely randomized design (CRD) with 3 replications. The natural storage performance of tubers were influenced by lifting period and /or tuber size. Most of the post harvest parameters of tuber viz., dry matter content, weight loss, rotten tuber, total soluble solid content, days to sprout initiation, days to shriveling and apical sprout length showed better performance with increasing lifting period. Among the tuber sizes, small sized tubers showed better post harvest performance compared to those of large and medium. Among the lifting periods and tuber sizes, L_3 (9 days after haulm killing) and small sized tuber showed better natural storage performance.

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ABBREVIATIONS

Abbreviation	Full word
%	Percentage
^{0}C	Degree Celsius (Centigrade)
ANOVA	Analysis of variance
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
CIP	International Potato Centre
cm	Centimeter
CRD	Completely Randomized Design
CV	Coefficient of Variation
DAS	Days After Storage
DMRT	Duncan’s Multiple Range Test
e.g.	‘for example’
etc	et cetra
et al.	And associates
FAO	Food and Agriculture Organization
Fig.	Figure
g	Gram
HPS	Hybrid Potato Seed
hr	Hour
LSD	Least Significant Difference
NS	Non Significant
PRC	Potato Research Centre
RH	Relative humidity
SAU	Sher-E-Bangla Agricultural University
t/ha	Ton per hectare
TCRC	Tuber Crops Research Centre
TPS	True Potato Seed
TSS	Total soluble solids
viz.	Namely

CHAPTER I

INTRODUCTION

CHAPTER I
INTRODUCTION

Potato is the fourth biggest crop of the world after wheat, rice and maize (FAO, 1995; Jones *et al*., 1994; Solomon and Barker, 2001). Now a day potato is the third staple food/vegetable crop could contribute in poverty alleviation and food security of Bangladesh. Nutritionally, the tuber is rich in carbohydrates or starch and is a good source of protein, vitamin C and the B vitamins, potassium, phosphorus, and iron. Most of the minerals and protein are concentrated in a thin layer beneath the skin, and the skin itself is a source of food fibre. It is estimated that local varieties were cultivated in about 184000 acres of land, producing 806000 m tons tubers and HYV varieties were cultivated in about 890000 acres of land, producing 7124000 m tons of tubers during 2009-2010 (BBS, 2010). Maximum cultivation and production of potato were found in the district of Dinajpur, Thakurgaon, Bogra, Joypurhat, Nilphamari and Munshigonj in Bangladesh.

Storage problem is also a serious problem in Bangladesh. In tropical and subtropical areas like Bangladesh, it is difficult to produce seed tubers of potato due to lack of appropriate storage facilities and transport, as well as the presence of viral diseases (Omidi *et al*., 2003). Due to its perishable nature farmers cannot store potato at home in large quantities for long period. Farmers in most places are under compulsion to sell out the major part of their product immediately after harvests with low price. The destruction of potato haulm is necessary to reduce late blight and virus spread, to reduce interference at harvest, to improve skin-set, to control tuber size and to improve storage quality. Early and thorough haulm destruction is an essential part of good seed production. So, lifting period can play important role on natural storage of potato from the above discussion, the said research is to be undertaken to find out the effect of lifting period on natural potato storage performance.

The use of True Potato Seed (TPS) for potato production has increased recently in Europe, North America and Asia, especially in the developing countries(Burton *et al*.,1989, Devaux, 1984; Song, 1984; Wiersema, 1986). In Bangladesh, this technology has been highly promising (Renia and Hest, 1998; Roy et al., 1999; Siddique and Rashid, 2000). However, knowledge on TPS progenies and appropriate lifting period for keeping quality under natural storage condition is not sufficient in our country. But the information of the storage and its mechanism is of great importance for the selection of TPS progenies having good keeping quality and better lifting period.

In Bangladesh, potato is generally stored in three ways, namely, (i) in cold stores under controlled environment and (ii) in the houses under controlled environment and (ii) in the houses under ordinary room conditions. In Bangladesh, the present cold storage capacity is only about 25% of the total potato production (BBS, 2010). An important characteristic of potato varieties is that, they can be stored under ordinary room conditions for a relatively longer period. Naturally the potato varieties are more convenient for those growers who wish to store their own produce for consumption and sale over a long period under ordinary room conditions and for use as seed tubers. Knowledge of proper storage environment obviously helps to maintain the quality, extend the storage period and increase the value of stored potato. Considering the above facts, the present work has been undertaken in order to study the storage behavior under ordinary room conditions.

In Bangladesh, very few reports are available regarding the lifting period which can play important role on natural storage of potato from the above discussion. The purpose of the present research is to provide the information on lifting period and natural storage performance of potato which to meet the producer demand. So, the present study to be undertaken to find out the effect of lifting period on natural potato storage performance with following objectives:

i. To identify the better lifting period of selected TPS progeny as influenced by natural storage condition;
ii. To study on the quality assessment of potato under storage period and
iii. To find out the suitable size of TPS cultivar for longer storage dormancy under the natural condition.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II
REVIEW OF LITERATURE

Potatoes (*Solanum tuberosum* L.) are an important source of nutrients and energy, globally representing the fourth most important food crop. Historically, successful potato production and storage has had a significant impact on world population growth and movement. In the 1800's, the failure of the Irish potato crop due to Late Blight (*Phytophthora infestans* (Mont.) de Bary) resulted in the death by starvation or emigration of millions of people from Ireland and other parts of Europe. Although this disease causes loss of the crop in the field, it is the resulting decay of the crop in storage that is most devastating. Potato production is increasing worldwide, primarily as a function of increasing yields, due to superior agronomic practices and improved disease control. The true potato seed (TPS) technology is a new and most popular among the farmers' especially to small farmers. Research work and results on storage behaviour of different TPS progenies at home and abroad are reviewed below.

2.1 Varietal performance on storage of potato

Storage problems most often occur because of conditions in the field and not conditions in storage. Adverse weather, disease or improper harvesting and handling of tubers can cause problems in storage. Tubers that are rotting, frozen, chilled or diseased must be managed differently than mature, sound tubers. Good storage management will help to salvage problem tuber lots, but storage will never improve a poor quality variety (Schwarz and Geisel, 2012).

Storability of tubers obtained from 9 hybrid True Potato Seed (TPS) progenies were compared with that of non-TPS cultivar 'Diamant' under ambient conditions (22.0-34.8°C and 58.0-93.6% RH). Dormant period, days to start shrinkage and days to 100% shrinkage of all TPS progenies were significantly longer than those of

‘Diamant’, especially in P-364 X TPS-67 and P-364 X TS-9. The results of correlation analysis among these parameters also indicated that the storability of the TPS progenies was superior to that of ‘Diamant’ (Roy *et al*., 2006). The rate of rotten tubers of all the TPS progenies, however, was significantly higher than that of ‘Diamant’ because of their high susceptibility to infectious diseases, indicating the importance of the selection of TPS progenies with high disease resistance during storage under ambient conditions. Tuber size also affected the storability of TPS progenies; small tubers were preferable to medium and large ones, except for their high shrinkability.

Storage behabiour of some exotic, recommended and advanced lines of potato were studied in 1991 at RARS, Jessore by storing their tubers in netted wooden box under natural condition (Rasul *et al*., 1997). Much variation was observed among the varieties/lines for all the characters studied. Percent weight loss was higher in exotic varieties (12.89-35.52%). Cent percent sprouting was earlier in recommended varieties/lines (96 days) than of exotic ones (118.7 days). On an average, tubers shrank earlier in existing varieties per lines than first generation materials. Rottage of tubers by bacterial soft rot (*Erwinia* sp) during storage varied from 31.3 to 36.8%. Recommended varieties Kufri, Sindhuri, Cardinal, Multa,advanced lines P-93 and first generation varieties viz. Granoloa, Modial, Producent and Vital performed the best on the basis of studied storage characteristics.

Van Ittersum *et al*. (1993) reported that re planted soon after their harvest give low yield because of dormancy and low growth vigor. In the research reported in this paper, we investigated the advancing effect of a haulm application of gibberellic acid (750 g GA/ha) 6 days before haulm pulling and its interaction with storage temperature regimes on the growth vigor of immaturely harvested seed tubers of three cultivars. The effects on tuber yield were also examined in one experiment. The storage regimes were: 18^0C continuously, hot pre-treatments of different duration (different periods at 28^0 C and subsequently 18^0 C) and a cold pre-treatment (20 days at 2^0 C and subsequently 18^0 C). Both a foliar spray with GA and storage at 28^0 C enhanced physiological aging of the tubers and greatly advanced the growth vigor, without negative effects on the morphology of the plants. At early planting, the effect of the treatments on tuber yield were small for Diamant (short dormancy), but strongly positive for Désirée and Draga (long dormancy).

In another experiment Hossain *et al*. (1992) reported that the maximum tuber weight loss was 31.15% recorded in the check variety Cardinal. In case of indigenous varieties, Jalpai lost maximum weight (19.16%) and Shilbilati lost the minimum (9.15%). The authors also reported that sprouting of tubers was started after 83 days in indigenous cultivars, while Cardinal sprouted first after 54 days of storage. In case of indigenous varieties, Bograi sprouted first after 70 days and Hagrai was most delayed (97 days).

Hossain and Rashid (1991) studied on storage quality of three sizes of tubers of eight TPS progenies against standard variety Cardinal for 120 days after harvest (April to July) under natural storage condition. Weight loss of tubers due to transpiration and respiration was 23.93% In TPS progenies and 11.95% in Cardinal with average monthly loss of 5.98% and 2.99%, respectively. Small size tubers were found to suffer most from dehydration. *Erwinia* sp. and *Fusarium* sp. have been identified to cause rotting of tubers in storage. The incidence of soft rot and dry rot were 33.40%

and 34.15%, respectively. No rot was observed in Cardinal during the period of study. Maximum rottage loss was recorded in large size tubers. Tubers of the TPS progenies sprouted earlier than Cardinal. Maximum number of sprouts per tubers and length of the longest sprout were recorded in TPS progenies. Tubers of TPS progenies shriveled earlier than Cardinal.

Hossain and Rashid (1991) reported 38.9% tuber loss of TPS progenies in natural storage. They also observed 25% weight loss in smaller and 21% in large tubers of TPS progenies after 120 days.

Usually, in Bangladesh, storage of potato starts during the month of March when both temperature and humidity rise up sharply which accelerate both physiological activities of tubers responsible for its deterioration and activities of the organisms responsible for various storage diseases. It has been reported (Anon., 1989) that the local varieties have a long period of dormancy and both table and seed potatoes can be stored at home without much physiological deterioration until the next planting season.

Sowa and Kuzniewicz (1989) studied the causes of loss during potato storage and indicated that the main causes of storage losses were respiration, evaporation and storage rot. In that study, storability was largely a varietal trait, although environmental conditions during both growth and storage were also important. Storage losses were lowest in the clone Clamp (4.4%) which increased with increasing temperature in the store (about 9%). Overall storage losses ranged from

9.4% in Janka to 32.5% in Sasanka. Storage losses due to rots ranged from 0.8% in Azalia to 22.69% in Sasanka.

Shriveling is an important character which impairs morphology as well as quality of tubers. It was reported that, on an average, shriveling was first noticed in the exotic varieties after 114 days of storing, whereas, shriveling was first appeared after 132 days in Surjamukhi (Anon., 1989), Dohazari Lal took the maximum period (178 days) to start shriveling.

In another experiment (Anon., 1989) it was found that the average dormancy period was highest in the local varieties (95 days) than the exotic varieties (83 days). Days required for shriveling in 100% tubers was maximum in local varieties (191 days), whereas in exotic varieties it was minimum (149 days). It was also found that the tubers of 6 local varieties, namely, Bograi Lal, Deshi Lal, Deshi Shada, Jhaubilati, Sada Pakri and Sada Patnai were stored up to 210 days without shriveling and all other local varieties were stored up to 180 days. Among the local varieties highest weight loss (23.9%) after 150 days was recorded from Lal Pakri and lowest from Lal Shil (8.5%) with an average loss of 13.9%.

During storage period sprouting of tubers is an important evaluatary character of varieties. As soon as sprouting starzs, the tubers rapidly loss its quality. Unfortunately, the potato tubers cannot store for more than 4 to 5 months without much deterioration of quality under ordinary storage conditions. Exotic varieties sprouted earlier than the local ones. Sprouting in local varieties was first to observed after 102 days (Anon., 1989). It was also observed that the average dormancy period was higher in local varieties (95 days) than the exotic varieties (83 days).

All the losses observed during potato storage, in respective of storage methods can be divided into two groups. Quantitative losses including weight losses of tubers due to vital process of tubers (respiration, evaporation, sprouting) and those resulting from parasites and parthognic microflora. The extent of such losses, apart from varietal properties is affected by the maturity and wholesomeness of tubers as well as internal condition of storage house. Quantitative losses are more difficult to detect since they do not reveal any decrease in the weight of tubers. They include quantitative losses of specific components but total content of dry matter not change significantly. Obviously, the difference between two groups of losses has only theoretical significance (Lisinska and Leszezynski., 1989).

Picha (1986) stated that no sprouting was found when cured sweet potatoes were stored at 15.6^{o}C and 90% RH for up to a year. The total weight loss of six cultivars were estimated. Transpiration played vital role for weight loss. Respiration contributed more total weight loss during the later period of storage than first month in storage.

In Korea Republic sweet potatoes cv. Hongmi, Eunmi, Hwangmi and Sinmi were stored in man-made cave (0-15^{o}C, 15-75% RH) or a stire house (15-18^{o}C, 80-85% RH). After a period of three months in the cave storage, tuber decomposition was less for sweet potatoes stored in the middle of the cave than for those stored at the entrance. Decomposition became the highest at cave than in the storehouse (Lee *et al*., 1985).

During the year 1980-81 the storage performance of some exotic and local cultivars of sweet potato was studied at the Bangladesh Agricultural University Farm. Among the cultivars studied, the storage ability of the cultivars ACC-6, TIS-3032, TIS-3247, AIS-230 and AIS-243-2 was quite good. New 10 and TIS 3032 showed the long dormancy period (Hossain *et al*., 1984).

The indigenous potato varieties show a capability to store well and have a general popularity for taste (Ahmad and Kader, 1981). They observed that when stored under non-refrigerated conditions, the indigenous varieties showed a longer dormancy and stored better.

Storage life of potato tubers mainly depends on temperature and humidity which influence evaporation, respiration, sprout growth and ultimately weight loss of tubers. Low temperature and high humidity in storage results minimum loss. The local varieties are liked by the farmers, keep well under ordinary room condition and possess a high market value (Khan *et al*., 1981). Theses varieties show differences in certain characteristics which are very important in connection with market value and local popularity.

Ahmad (1979) reported that the farmers of the north-west part of Bangladesh use local varieties of potato instead of high yielding exotic varieties only because they have a longer dormancy and keeping quality even under ordinary storage.

2.2 Effect of harvest period and sizes of potato on storage

Hossain *et al*. (1995) worked on physiological behavior and storage quality of three sizes of tubers of eight British potato varieties in their second and third generations which have been compared with a recommended variety Diamant of Dutch origin. Average weight loss of the British varieties due to dehydration was 19.0% In second and 17.55% in the third generation, compared to 18.16 and 20.55% tuber loss respectively in the controls. Small tubers were found to suffer most form dehydration. *Erwinia* spp and *Fusarium* sp. were identified as the cause of rot diseases. Average loss of the British varieties due to rotting was 13.33% in the second and 8.75% in the third generation, compared with 10.0 and 16.67%, respectively in the controls. Maximum loss due rot was observed in the larger tubers. Ailsa in the second and Kingston and Pentaland squire in the third generation were found to perform better than the controls for days to sprouting, 100% sprouting and shriveling. For all these characters, larger tubers performed less well than the medium sized and small tubers. Number of sprouts, sprout length and weight was lower in Ailsa, Kingston and Pentland Square than the control. Physical condition of tubers of the British varieties was better than the control in both generations. Larger and smaller tubers responded easily for this character. Among the British varieties Kingston and Pentland Square were very good, but the performance of Ailsa was excellent.

Dry-matter concentration and dormancy were studied in minitubers of cvs Agria and Liseta, using five fresh weight classes (<0.50 g, 0.50–0.99 g, 1.00–1.99 g, 2.00–2.99 g and ≥3.00 g) and three successive harvests of the same plantlets (Willemien, 1993). The average dry-matter concentration increased with tuber weight for tubers from the second and third harvests. In minitubers ≥0.5 g, dry-matter concentration was higher in tubers from later harvests. The dormant period (days from harvest to 50%

sprouting) was longer in minitubers with lower than higher weights, and longer in tubers from the first harvest than from later harvests. A cold-storage period of 6 weeks, starting 14 days after harvest, reduced the dormant period by an average of 11 days.

Hossain *et al*. (1992a) studied storage quality of three sizes of tubers of 21 Dutch potato cultivars against one recommended cultivar Diamant (Check) for 180 days under natural storage condition. The mean weight loss of tubers due to dehydration was 21.38% in Dutch cultivars and 20.26% In the check with monthly loss of 3.56% and 3.42%, respectively. Small sized tuber were found to suffer most from dehydration. *Erwinia* sp. and *Fusarium* sp. have been identified to cause tuber rot in storage loss of tubers due to rotting of 12.57% in Dutch cultivars and 10.00% in the check. No rot was observed in the cultivars Alkon, Binell, Cosmos, Liseta, Mondial and Vital during the period of study. Maximum loss due to rots was observed in larger tubers. The four cultivars, Alkon, Escort, Liseta and Mondial performed better than the check for days to initial sprouting, 100% sprouting and shriveling, number sprout, length and weight of sprouts were also lower in the check. For all these characters, large tubers were found to respond earlier to rot than medium and small sized tubers. Shrivelling was the maximum in the tested materials than the check larger and smaller tubers respond equally for these characters.

Hossain *et al*. (1992b) studied on keeping quality of three sizes of tubers of 20 indigenous potato cultivars for 210 days (March to September) under natural storage condition. Weight loss was 15.23% for indigenous cultivars and 31.15% for Cardinal, while rottage loss was 3.17% and 39.16%, respectively. Smaller tubers suffered maximum weight loss and minimum rottage loss. Indigenous cultivars showed better performance for qualitative characters like days to sprouting, percentage of shriveling while the check variety, Cardinal was better for quantitative characters like number, length and weight of sprouts per tuber, respectively. No rot was observed in cardinal during the period of study. Maximum number of sprouts per tuber and length of the longest sprout were recorded In TPS progenies. Tuber of TPS progenies shriveled earlier than Cardinal.

The dormant period was also affected by the tuber size. The small tubers had a significantly longer dormant period than medium and large ones (91.1 vs. 69.4-76.9 days), as reported previously for some non-TPS potato cultivars (Hossain *et al*., 1992).

Schaupmeyer (1992) provide detailed reviews of the postharvest management of potatoes. Potatoes are graded prior to storage to remove obviously deformed, diseased or damaged tubers. Placing quality potatoes into storage will help ensure that a higher quality of potatoes comes out of storage. Low quality potatoes going into storage serve as an initial inoculum source for disease which can subsequently spread within storage. Low quality potatoes also contribute to a reduction in the overall quality of storage conditions. For example, increased respiration by damaged tubers can lead to pockets where the storage temperature is elevated. These elevated temperatures in turn accelerate moisture loss and development of disease.

During mechanical harvest, potato tubers are often slightly damaged (abrasions, cuts, bruises), particularly if their skins are not completely developed at the time of harvest. The damaged areas are susceptible to infection by pathogens introduced from the surrounding soil (such as *Fusarium spp.*), air or water-borne spores (e.g. *H. solani* or *P. infestans*) or by contact with other infected tubers (e.g. *E. carotovora*). These wound pathogens may develop and/or spread during the subsequent storage, causing significant losses of weight and quality (Morris *et al*., 1989). To decrease losses to post-harvest diseases introduced at wound sites, a curing period is carried out at the commencement of storage. During this two to three week period, the crop is stored at 15°C with abundant volumes of air pumped through the pile. This curing period promotes the development of wound periderm tissue, thus reducing the number of open wounds and potential entry points for pathogenic organisms. The wound periderm layer also reduces water loss from the wound site.

2.3 **Effect of storage behaviour on physiological and chemical changes of potato**

Malik *et al*. (2001) reported that the potato is the major vegetable being grown in Pakistan and its post harvest losses occur during harvesting, handling, transportation and storage etc. Different types of on-farm storage systems of potato were studied and data regarding temperature and humidity were recorded. Results from the naturally ventilated and forced draft ventilated stores showed almost no different in temperature and humidity regimes, whereas these parameters were no high side in the traditional clamp. Conclusion was drawn that naturally ventilated storage system of potato is better. Post harvest technology of potato is being transferred to the growers in which stress is focused on different aspects of post harvest technology of potatoes. Research studies on the use of sprout suppressants yielded encouraging results.

In Bangladesh, potatoes are generally harvested in February to March, when both temperature and humidity begin to rise sharply. Under such conditions, the tubers terminate dormancy and begin to sprout, which results in a decrease of their quality due to changes such as shrinkage, weight loss and rot (Devendra *et al*., 1995). Under ambient conditions in Bangladesh, 20 to 80% of the tubers have been lost.

Wiersema and Cabellow (1987) were investigate on the tuber-to-tuber variability in storage behaviour of seed tubers from true potato seed was compared with that in clonal seed tubers after storage in the dark, in diffused light, or in diffused light with a single de-sprouting. The variability was estimated by calculating standard deviations of length, number and weight of sprouts, and tuber weight loss. After dark storage, the variability of these variables was greater in seed tubers from true potato seed than in clonal seed tubers. After storage in diffused light with a single desprouting, the variability of number, length and weight of sprouts of seed tubers from true seed was not statistically different from that observed in clonal seed tubers. All storage treatments resulted in a greater variability of tuber weight loss in seed tubers from true potato seed than in clonal tubers.

Dayal and Sharma (1987) reported that stored potatoes deteriorate in quality due to a number of reasons. These are weight loss, sprouting and formation of little tuber and internal sprouts. Such deterioration is pronounced under relatively high temperature. Storage methods of overcoming these problems and prolonging the store life of potatoes have been reported. Sprout suppression are used for prolonging the storage. Successive de-sprouting of storage potatoes can be employed for harvesting sprouts for use in rapid multiplication techniques.

George *et al*. (1985) stated that 10 clones were stored at ambient temperature and humidity. Among them 8 had tubers storage periods of <5 weeks. The main cause of poor storage ability was microbial infections, dehydration’s and sprouting.

In Bangladesh, farmers need to store their potatoes from March to September. By this time, a certain percentage of tubers is damaged due to dehydration and rottage. Khan *et al*. (1984) reported 40.6% tuber loss in natural storage. 3 In an experiment, Roy and Hossain (1981) showed that storage of potatoes under non-refrigerated condition was very much promising. A loss of 8-10% due to rottage and shrinkage occurred.

In Bangladesh, farmers need to store their potatoes from March to September. Tuber loss due to dehydration and rottage under natural storage was reported up to 80.0% by Hashem (1979) and 40.6% by Khan *et al*. (1981).

Verma (1976) reported rotting of tubers was the highest for Kufri Sindhuri when stored without temperature control under farm conditions. Total sugar concentration increased in all varieties during storage but without temperature control reducing sugar content only increased in Kufri Chandramukhi.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III
MATERIALS AND METHODS

The materials and methods of this research work were described in this chapter as well as on experimental site, materials used, experimental layout and design, source of seed, data collection etc within research period. Overall discussion about materials on natural storage performance of potato derived from true potato seed as affected by lifting period after haulm killing. The detailed methodology followed to conduct the experiment is described in the following:

3.1 Experimental site

The present experiment was conducted at the Laboratory of the Department of Agronomy, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from 6 March to 15 August, 2011 to study the natural storage performance of potato as affected by lifting period after haulm killing.

3.2 Conditions of storage room

The temperature and relative humidity of the storage room were recorded daily during the study period with a digital thermo hygrometer (THERMO, TFA, Germany). The minimum and maximum temperature during the study period of the storage room was 26.8 ^{o}C to 33.2^{o}C, respectively. The minimum and maximum relative humidity was 72.75% (Appendix I).

3.3 Experimental materials

The materials used for the experiment were the harvested tubers of BARI TPS-1. Different sizes potato tuber (F_1C_1-first clonal generation) derived from true potato seed were collected at varying lifting period from Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka- 1207. The collected tubers were free of any visible defects, disease symptoms and insect infestations and transported to the

Laboratory of the Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Dhaka with careful handling to avoid disease and injury.

3.4 Experimental treatments and design

Tubers were randomly selected after harvest from the experimental field and placed on the floor of the Laboratory at natural condition to find out the better lifting period as affected by tuber sizes under quality observation. The potato were harvested as treatments as per the following methods. The experiment consisted of two factors as follows:

Factor A: Five harvesting periods of 3 days interval

L_0 : 0 day after haulm killing

L_1 : 3 days after haulm killing

L_2 : 6 days after haulm killing

L_3 : 9 days after haulm killing

L_4 : 12 days after haulm killing

Factor B: Three tuber sizes of BARI TPS-1

L : Large (>45 mm)

M : Medium (28-45 mm)

S : Small (<28 mm)

The experiment was laid out in a Completely Randomized Design (CRD) with 3 replications.

3.5 Methods of the study

Three sizes of tubers (>45 mm, 28-45 mm and <28 mm) were included in the study. Thirty tubers consisting (10 tubers in each unit), Initial weight of tubers of each grade for each variety was taken at 06 March 2011. The tuber of each grade was kept in netted plastic basket and was stored in a well ventilated room under diffused light condition in the laboratory. Weighing of tubers was continued at 30 days interval for 120 Days After Storage (DAS). Tubers were observed at alternate days for recorded rotted tubers. Tubers were checked every day for days to sprouting, 100% shriveling counted for 180DAS. Number of sprouts tuber^{-1}, length and weight of sprout and physical condition of tuber were recorded at 120days. Physical condition of tubers was evaluated by eye estimation following an arbitrary scale (1= no shrinkage and 5= maximum shrinkage).

3.6 Parameters studies

The following parameters were studied in the present experiment**:**

3.6.1 Dry matter (%) of peel of potato

Fresh and dry weight percentage of peel was recorded at 30, 60, 90 and 120Days After Storage (DAS). Peel of potato was dried in Oven at 72^{o}C for 72 hrs and then the dry matter percentage of peel was recorded. Dry matter percentage of peel was also recorded on the basis of initial weight.

3.6.2 Dry matter (%) of flesh of potato

Dry matter percentage of flesh was also recorded at 30, 60, 90 and 120 DAS. Flesh of potato was also dried in oven at 72^{o}C for 72 hrs and then the dry matter percentage of flesh was recorded. Dry matter percentage of flesh was also recorded on the basis of initial weight.

3.6.3 Weight loss percentage

Potato was stored as per treatment and their initial weight was taken. Weight loss percentage was recorded at different days after storage (30, 60, 90 and 120 DAS) from those stored potato.

3.6.4 Length of apical sprout (cm)

Apical sprout length data was recorded first time when the 100% sprouting was done. Again the length of sprout data was also recorded at the end of the experiment at 180 days. Their average data were taken for length of sprout.

3.6.5 Rotten tubers percentage

After the harvest, potato was stored for 120 Days. Rotten tubers percentage was determined at different days after storage (60, 90 and 120 DAS).

3.6.6 Total soluble solids (TSS)

Total soluble solids (TSS) content of potato tuber was estimated using Abbe’s Refractometer. A drop of potato juice squeezed from the tuber was placed on the prism of the refractometer, and TSS was recorded as %Brix from direct reading of the instrument. Temperature corrections was made using the temperature correction chart.

3.6.7 Days to sprout initiation

The tubers were keenly observed for sprout initiation. Data were recorded when a very small sprout head was emerged at eyes of tubers.

3.6.7 Days to start shriveling

The tubers were keenly observed for tuber shriveling. Shriveling indicates physical condition of the tubers.

3.6.9 Days to 100% shriveling

The data were recorded for shriveling of 100% shriveling following arbitrary scale

1-5 (1= no shriveling and 5= maximum shriveling)

3.6.10 Apical sprouts length (cm)

Apical sprout length data was recorded when the 100% sprouting was done. Their average data were taken for length of sprout.

3.6.11 Weight loss (%) at 120DAS

At the end of the experiment (at 120 days after storage), remaining good tubers were recorded and their percentage were calculated on the basis of initial weight of tuber.Weight loss was calculated using the following formula:

Percent weight loss (%) WL = (IW-FW)/IW× 100

Where, WL = Percent total weight loss

IW = Initial weight of tubers (g)

FW = Final weight of tubers (g)

3.7 Statistical analysis

The collected data on various parameters were statistically analyzed using MSTAT statistical package. The analysis of variances (ANOVA) for different parameters was performed and means were compared by the Duncan's Multiple Range Test (DMRT). The significance of difference between the pairs of means was compared at the 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV
RESULTS AND DISCUSSION

The experimental results was obtained due to the effect of different lifting period and sizes of tubers on long term storage under natural condition. The data were recorded at different days after storage (DAS) on different characteristics of physical, chemical and microbial properties. These results are presented and discussed in this chapter with some Tables and Figures, and possible interpretations were made as required.

4.1 Dry matter (%) of peel of potato

4.1.1 Effect of lifting period

Effect of lifting period showed significant variation in respect of dry matter percentage of peel at different days after storage (DAS) (Appendix II). Significant variation data was also present in Table 1. The highest dry matter percentages of peel of potato (21.44, 21.72,25.95, 27.96 and 22.90 %) were taken from the harvested potato of 12 days after haulm killing (L_4) at initial 30,60, 90 and 120 days after storage respectively. Similarly, the lowest dry matter weight percentages of peel of potato (14.51, 14.18, 17.84 and 19.93%) were obtained from the similar DAS, respectively. At 90 DAS, the highest dry matter percentage of peel of potato (27.96%) was recorded at 12 days after haulm killing (L_4) and the lowest dry matter weight percentage of peel (14.18%) was observed at 0 days after haulm killing (Table 1).In general, increasing dry matter content increased the lifting period. It observed that the significant variations were found in dry matter content at all the days after storage due to different lifting period. So, dry matter percentage increase with the increasing lifting period time.

Table 1: Effect of lifting period on dry matter (%) of peel of potato at different days after storage

Lifting period	Dry matter (%) of peel of potato at different DAS				
	0	**30**	**60**	**90**	**120**
L_0	14.51 d	14.18 e	17.84 e	19.93 d	21.90 b
L_1	16.27 c	16.60 d	19.41 d	22.27 c	17.79 d
L_2	17.87 b	18.14 c	22.44 c	24.48 b	19.09 c
L_3	20.78 a	20.96 b	24.93 b	27.25 a	21.79 bc
L_4	21.44 a	21.72 a	25.95 a	27.96 a	22.90 a
CV (%)	4.11	3.74	3.27	3.66	5.09
Level of Significance	**	**	**	**	**
SE	0.25	0.23	0.24	0.30	0.24

Different letter(s) within columns indicate significant difference by DMRT

DAS= Days after storage
L_0= 0 days after haulm killing
L_1= 3 days after haulm killing
L_2= 6 days after haulm killing
L_3= 9 days after haulm killing
L_4= 12 days after haulm killing

4.1.2 Effect of tuber size

A significant variation was found due to the effect of different tuber size on dry matter percentage at different days after storage (Appendix II). At 0 DAS, the highest dry matter weight percentage (15.11 %) was recorded from large tuber sizes and the lowest (13.43 %) was found from medium size tuber where small size tubers produced the average results (14.0 %). Similarly, large sizes tuber produced the highest dry matter weight percentage of peel **(**20.18, 20.36, 24.04 and 26.53%) at 30, 60, 90 and 120 days after storage, respectively. Similarly, small sizes tuber showed the minimum result (16.51, 16.64, 20.20 and 22.70%) at 30, 60, 90 and 120 DAS, respectively.

Table 2: Effect of tuber size on peel and dry matter (%) at different days after storage

Sizes	Dry matter (%)				
	0	30	60	90	120
Small	14.0 b	16.51 c	16.64 c	20.20 c	22.70 c
Medium	13.43 c	17.83 b	17.95 b	22.10 b	23.95 b
Large	15.11 a	20.18 a	20.36 a	24.04 a	26.53 a
CV (%)	4.11	3.74	3.27	3.66	5.09
Level of Significance	**	**	**	**	**
SE	0.20	0.18	0.19	0.23	0.19

Different letter(s) within columns indicate significant difference by DMRT

4.1.3 Combined effect of lifting period and sizes of tubers

Combined effect between lifting period and tube sizes showed significant variation in respect of dry matter weight percentage at different days after storage (Appendix II). Among the tuber sizes, large sizes tuber gave the highest dry matter weight percentage (23.10%) at 0 DAS when the lifting period was 12 days after haulm killing (L_4) which was statistically similar to 9 days after haulm killing at the similar sizes tuber (22.78%). However, the lowest dry matter weight percentage (12.90%) was recorded in small sizes tuber of 0 days after haulm killing at 0 days after storage. Similarly, the lifting period of 12 days after haulm killing with medium sizes tuber showed the highest dry matter weight percentage (23.43 and 29.20%) at 30 and 120 DAS, respectively which was statistically similar to same sizes tuber of 9 days after haulm killing potato (22.92 and 28.47%, respectively). At 60 DAS, the highest dry matter weight percentage (33.02%) was found in large size tuber of 0 days after haulm killing potato where medium sizes tuber gave the lowest dry matter weight percentage (7.30%) when the lifting period of 9 days after haulm killing. On the other hand, the lowest dry matter weight percentage (12.15, 15.71 and 18.00%) was obtained from the 0 days after haulm killing lifting period with small sizes tuber at 30, 90 and 120 DAS, respectively (Table 3).

Table 3: Combined effect of different lifting period and tuber sizes on peel of potato and dry matter (%) at different days after storage

Lifting period	**Sizes**	**Dry matter (%)**				
		0	**30**	**60**	**90**	**120**
L_0	S	12.90 g	12.15 g	14.47 d	15.71 h	18.00 g
	M	14.61 f	14.11 f	18.21 bc	17.27 g	19.62 f
	L	16.02 e	16.27 e	33.02 a	20.55 ef	22.17 de
L_1	S	14.05 fg	14.65 f	18.92 b	16.82 gh	19.97 f
	M	16.21 e	16.62 e	17.19 c	20.00 f	21.66 e
	L	18.56 d	18.53 d	17.26 c	21.40 e	25.18 c
L_2	S	16.04 e	16.33 e	17.74 bc	20.66 ef	23.51 d
	M	17.12 e	17.44 de	14.94 d	21.81 de	22.33 de
	L	20.43 bc	20.64 bc	7.79 gh	24.85 c	27.61 ab
L_3	S	19.54 cd	19.86 c	10.96 e	22.86 d	25.53 c
	M	20.02 bc	20.10 c	9.49 f	25.63 bc	27.73 ab
	L	22.78 a	22.92 a	8.94 fg	26.29 ab	28.47 a
L_4	S	20.03 bc	20.22 c	7.88 gh	24.94 c	26.28 bc
	M	21.20 b	21.493 b	7.30 h	25.80 bc	28.39 a
	L	23.10 a	23.43 a	8.53 fgh	27.11 a	29.20 a
CV (%)		4.11	3.74	3.27	3.66	5.09
Level of Significance		**	**	**	**	**
SE		0.43	0.40	0.42	0.42	0.52

Different letter(s) within columns indicate significant difference by DMRT

S= small M= medium L= large
DAS= Days after storage L_0= 0 days after haulm killing L_1= 3 days after haulm killing
L_2= 6 days after haulm killing L_3= 9 days after haulm killing L_4= 12 days after haulm killing

4.2 Dry matter percentage of flesh of potato

4.2.1 Effect of lifting period

A significant variation was found due to the effect of lifting period in respect of dry mater percentage of flesh at different days after storage (Appendix II). Among the lifting period, 12 days after haulm killing gave the highest dry matter weight percentage of flesh (20.55, 21.28, 22.31, 24.60 and 27.32%) at the whole storage period viz., 0, 30, 60, 90 and 120 days after storage, respectively. On the otherhand, 0 day after haulm killing produced the lowest dry matter content percentage of flesh (12.85, 13.52, 15.52, 16.55 and 18.81%) at the similar storage period, respectively (Table 4). From the table 4, it was also showed that the dry matter content of flesh of potato gradually increased with the increasing lifting period as well as the storage period.

In general, increasing dry matter content increased the lifting period and flesh weight of potato. It was also observed that the significant variations were found in dry matter content at all the days after storage due to different lifting period. So, dry matter percentage increased with the increasing lifting period.

Table 4. Effect of lifting period and dry matter (%) of flesh of potato at different days after storage

Lifting period	Dry matter (%)				
	0	30	60	90	120
L_0	12.85 e	13.52 e	15.52 e	16.55 e	18.81 e
L_1	15.02 d	15.46 d	17.56 d	18.35 d	20.75 d
L_2	16.31 c	16.89 c	19.43 c	21.31 c	23.62 c
L_3	19.39 b	19.93 b	21.59 b	23.71 b	26.11 b
L_4	20.55 a	21.28 a	22.31 a	24.60 a	27.32 a
CV (%)	4.26	4.14	3.58	3.41	3.05
Level of Significance	**	**	**	**	**
SE	0.24	0.24	0.23	0.24	0.24

Different letter(s) within columns indicate significant difference by DMRT

DAS= Days after storage
L_0= 0 days after haulm killing
L_1= 3 days after haulm killing
L_2= 6 days after haulm killing
L_3= 9 days after haulm killing
L_4= 12 days after haulm killing

4.2.2 Effect of tuber sized

Analysis of variance showed the significant differences among the tuber sizes in respect of dry matter **(%)** of flesh of potato (Appendix II). Among the tuber sizes, the highest dry matter **(%)** of flesh (18.52, 19.15, 21.74, 23.18 and 25.60%) was observed in large sizes tuber where small sizes tuber produced the lowest (15.33, 15.89, 17.24, 18.59 and 21.35%) at 0, 30, 60, 90 and 120 DAS, respectively (Table 5). Observation showed that the dry matter content of flesh gradually increased with the increasing storage period and lifting period in that case large tuber produced the highest and small tuber showed the lowest result on dry matter percentage of flesh (Table 5).

Table 5: Effect of tuber sizes on dry matter (%) of flesh of potato at different days after storage

Sizes	Dry matter (%)				
	0	**30**	**60**	**90**	**120**
Small	15.33 c	15.89 c	17.24 c	18.59 c	21.35 c
Medium	16.62 b	17.21 b	18.87 b	20.95 b	23.02 b
Large	18.52 a	19.15 a	21.74 a	23.18 a	25.60 a
CV (%)	4.26	4.14	3.58	3.41	3.05
Level of Significance	**	**	**	**	**
SE	0.18	0.19	0.18	0.18	0.18

Different letter(s) within columns indicate significant difference by DMRT
DAS= Days after storage L_0= 0 days after haulm killing L_1= 3 days after haulm killing
L_2= 6 days after haulm killing L_3= 9 days after haulm killing L_4= 12 days after haulm killing

4.2.3 Combined effect of lifting period and tuber sized

Combined effect of different lifting period and 3 tuber sizes significantly influenced on dry matter percentage at different days after storage (Appendix II). Dry matter (%) of flesh was the maximum (22.05, 22.94, 24.70, 26.89 and 28.73%) in large tuber when the lifting period was 12 days after haulm killing at different storage period, respectively which was closely followed by the similar sizes of tuber with 9 days after haulm killing (21.08, 21.78, 23.76, 25.04 and 27.14%, respectively). Similarly, the lowest dry weight of flesh (11.18, 11.98, 13.24, 14.47 and 16.29%) was recorded from the lifting period of 0 days after haulm killing when the tuber size was small (Table 6). From the table 6, it was also found that the dry matter weight of flesh progressively increased with the increasing level of lifting period and storage time. On the other hand, small, medium and large tuber also showed the lowest, average and higher performance, respectively as per lifting period.

Table 6: Combined effect of different lifting period and tuber size dry matter (%) of flesh of potato at different days after storage

Lifting period	Sizes	Dry matter (%)				
		0	30	60	90	120
L_0	S	11.18 j	11.98 i	13.24 i	14.47 i	16.29 h
	M	12.92 i	13.53 h	15.68 h	16.21 i	18.41 g
	L	14.40 h	15.04 g	17.63 g	18.98 gh	21.73 ef
L_1	S	13.03 i	13.53 h	15.63 h	15.25 ij	17.55 g
	M	15.09 gh	15.79 fg	17.31 g	18.38 h	20.55 f
	L	16.95 ef	17.05 f	19.74 f	21.41 de	24.15 d
L_2	S	15.08 gh	15.48 g	17.28 g	19.73 fg	22.90 e
	M	15.78 fg	16.28 fg	18.16 g	20.63 ef	21.70 ef
	L	18.08 de	18.91 de	22.86 bc	23.58 c	26.25 bc
L_3	S	18.04 de	18.54 e	19.85 f	21.39 de	24.22 d
	M	19.06 cd	19.46 de	21.16 de	24.71 bc	26.96 bc
	L	21.08 ab	21.78 ab	23.76 ab	25.04 b	27.14 b
L_4	S	19.33 cd	19.93 cd	20.21 ef	22.08 d	25.76 c
	M	20.26 bc	20.96 bc	22.02 cd	24.82 bc	27.48 b
	L	22.05 a	22.94 a	24.70 a	26.89 a	28.73 a
CV (%)		4.26	4.14	3.58	3.41	3.05
Level of Significance		**	**	**	**	**
SE		0.41	0.42	0.39	0.41	0.41

Different letter(s) within columns indicate significant difference by DMRT

S= small M= medium L= large
DAS= Days after storage L_0= 0 days after haulm killing L_1= 3 days after haulm killing
L_2= 6 days after haulm killing L_3= 9 days after haulm killing L_4= 12 days after haulm killing

4.4 Weight loss percentage of tubers

4.4.1 Effect of lifting period

Weight loss of tubers was significantly influenced on the effect of lifting period at different days after storage (Appendix IV). Among the lifting period, 9 days after haulm killing (L_3) showed the minimum weight loss (5.53, 7.17, 8.03 and 15.27%) at

30, 60, 90 and 120 DAS, respectively which was statistically more or less similar with the lifting period of 6 days after haulm killing (5.83, 7.80, 8.53, 15.67%) and 12 days after haulm killing (5.93, 7.93, 8.54 and 17.40%). However, the maximum weight loss (6.87, 9.33, 11.87 and 18.07%) was found from the lifting period of 0 days after haulm killing at 30, 60, 90 and 120 days after storage, respectively (Table 7). Weight loss is the most important parameter of the storage period in that case minimum weight loss increase the storage period. Beside, lifting period closely correlated to weight loss because of mature potato gave the high dormancy of storage. Among the lifting period, 9 days after haulm killing potato was mature and it was present the high dormancy of storage. Beside, another lifting period viz. 6 and 12 days after lifting period storage potato was mature and they also showed more or less similar dormancy in storage period and 0 days after haulm killing potato showed maximum weight loss in case of immature potato.

Table 7: Effect of lifting period on weight loss of tuber tuber (%) at different days after storage

Lifting period	Weight loss of tuber(%)			
	30	**60**	**90**	**120**
L_0	6.87 a	9.33 a	11.87 a	18.07 a
L_1	6.41 ab	8.11 b	9.64 b	16.94 b
L_2	5.83 bc	7.80 bc	8.53 c	15.67 c
L_3	5.53 c	7.17 c	8.03 d	15.27 c
L_4	5.93 bc	7.93 b	8.54 c	17.40 ab
CV (%)	11.45	8.72	7.57	4.22
Level of Significance	**	**	**	**
SE	0.23	0.24	0.24	0.23

Different letter(s) within columns indicate significant difference by DMRT

DAS= Days after storage
L_0= 0 days after haulm killing
L_1= 3 days after haulm killing
L_2= 6 days after haulm killing
L_3= 9 days after haulm killing
L_4= 12 days after haulm killing

4.4.2 Effect of tuber sizes on weight loss of tuber

Main effect sizes of tubers also found significant variation in relation to weight loss of tubers at 30, 60, 90 and 120 days after storage (Appendix IV). Among the tuber sizes, small tubers produced the minimum weight loss (5.48, 7.24, 8.50 and 158.70%) and larger tubers showed the maximum weight loss (6.92, 8.88, 10.01 and 17.66%) at 30, 60, 90 and 120DAS, respectively (Table 8). From the table 8, it was found that the small tuber produced the minimum and larger tuber showed the maximum weight loss to compare initial weight of tubers at different days after storage. So, the small tuber showed the long storage period than larger as well as medium tuber. Weight loss of potato also increases with the increasing storage period (Table 8).

Table 8: Effect of tuber sizes on weight loss (%) of tuber at different days after storage

Sizes	**Weight loss(%)**			
	30	**60**	**90**	**120**
Small	5.48 b	7.24 c	8.50 c	15.70 c
Medium	5.94 b	8.08 b	9.46 b	16.64 b
Large	6.92 a	8.88 a	10.01 a	17.66 a
CV (%)	11.45	8.72	7.57	4.22
Level of Significance	**	**	**	**
SE	0.18	0.18	0.18	0.18

Different letter(s) within columns indicate significant difference by DMRT

DAS= Days after storage
L_0= 0 days after haulm killing
L_1= 3 days after haulm killing
L_2= 6 days after haulm killing
L_3= 9 days after haulm killing
L_4= 12 days after haulm killing

4.4.3 Combined effect of lifting period and tuber size

Analysis of variance on weight loss of tubers showed significant variation due to the combined effect of lifting period and tuber sizes at different days after storage (Appendix IV). The minimum weight loss (4.80%) was found in small tubers when the lifting period was 12 days after haulm killing in case of mature tubers which was statistically identical (4.90) with the same tuber sizes at 6 and 9 days after haulm killing at 30 DAS. However, the minimum weight loss (7.40%) was taken in large tuber size of 12 days after haulm killing. Similarly, the minimum weight loss (5.90, 7.70 and 13.70%) was recorded in small tuber when the lifting period was 9 days after haulm killing at 60, 90 and 120 DAS, respectively. On the other hand, large tubers also showed the maximum weight loss (9.70 and 13.10%) with the lifting period of 0 days after haulm killing at 60 and 90 DAS, respectively. In contract, similar tuber also produced the maximum weight loss (19.40%) from the 12 days after haulm killing at 120 DAS (Table 9). From the table 9, it was also clear that the small tuber perform the best on weight loss with all lifting periods than medium and larger tuber. Beside, lifting period of 9 days after haulm killing also showed the higher performance to compare another lifting period at the whole storage period. Minimum weight loss of tuber produced the long dormancy of storage in that case small tuber of 9 days after haulm killing gave the long dormancy of storage potato in this study.

Table 9: Combined effect of different lifting period and tuber sizes on weight loss (%) of tuber at different days after storage

Lifting period	Tuber Size	Weight loss (%)			
		30	60	90	120
L_0	S	6.80 a-c	8.90 a-d	10.11 bc	17.80 bc
	M	6.70 a-c	9.40 ab	12.50 a	18.00 bc
	L	7.10 ab	9.70 a	13.01 a	18.40 ab
L_1	S	6.00 b-d	7.70 d-f	8.90 c-g	16.90 c
	M	6.30 a-d	8.10 b-f	9.70 b-d	16.80 c
	L	6.91 a-c	8.51 a-e	10.31 b	17.11 bc
L_2	S	4.90 e	6.90 fg	7.80 fg	14.90 d
	M	5.80 b-e	7.80 c-f	8.60 d-g	15.40 d
	L	6.80 a-c	8.70 a-d	9.20 b-e	16.70 c
L_3	S	4.90 e	5.90 g	7.70 g	13.70 e
	M	5.30 de	7.20 ef	8.00 e-g	15.40 d
	L	6.40 a-d	8.40 a-e	8.40 d-g	16.70 c
L_4	S	4.80 e	6.80 fg	8.00 e-g	15.20 d
	M	5.60 c-e	7.90 c-f	8.51 d-g	17.60 bc
	L	7.40 a	9.10 a-c	9.10 b-f	19.40 a
CV (%)		4.06	8.72	7.57	4.22
Level of Significance		**	**	**	**
SE		0.40	0.41	0.41	0.41

Different letter(s) within columns indicate significant difference by DMRT at 5% level of probability

S= small M= medium L= large
DAS= Days after storage L_0= 0 days after haulm killing L_1= 3 days after haulm killing
L_2= 6 days after haulm killing L_3= 9 days after haulm killing L_4= 12 days after haulm killing

4.5 Length of sprout (cm)

4.5.1 Effect of lifting period

Length of sprout varied significantly ($P<0.01$) due to the effect of different lifting period (Appendix V). Significant variation data was present in Fig. 1, From the Figure:1 it was observed that the longest sprout (1.77 cm) was found from the lifting period of 0 days after haulm killing (L_0) which was followed by the second highest (1.60 cm) with the lifting period of 3 days after haulm killing (L_1). However, the shortest sprout (1.28 cm) was recorded from the lifting period of 12 days after haulm killing (L_4) storage potato.

DAS= Days after storage
L_0= 0 days after haulm killing
L_1= 3 days after haulm killing
L_2= 6 days after haulm killing
L_3= 9 days after haulm killing
L_4= 12 days after haulm killing

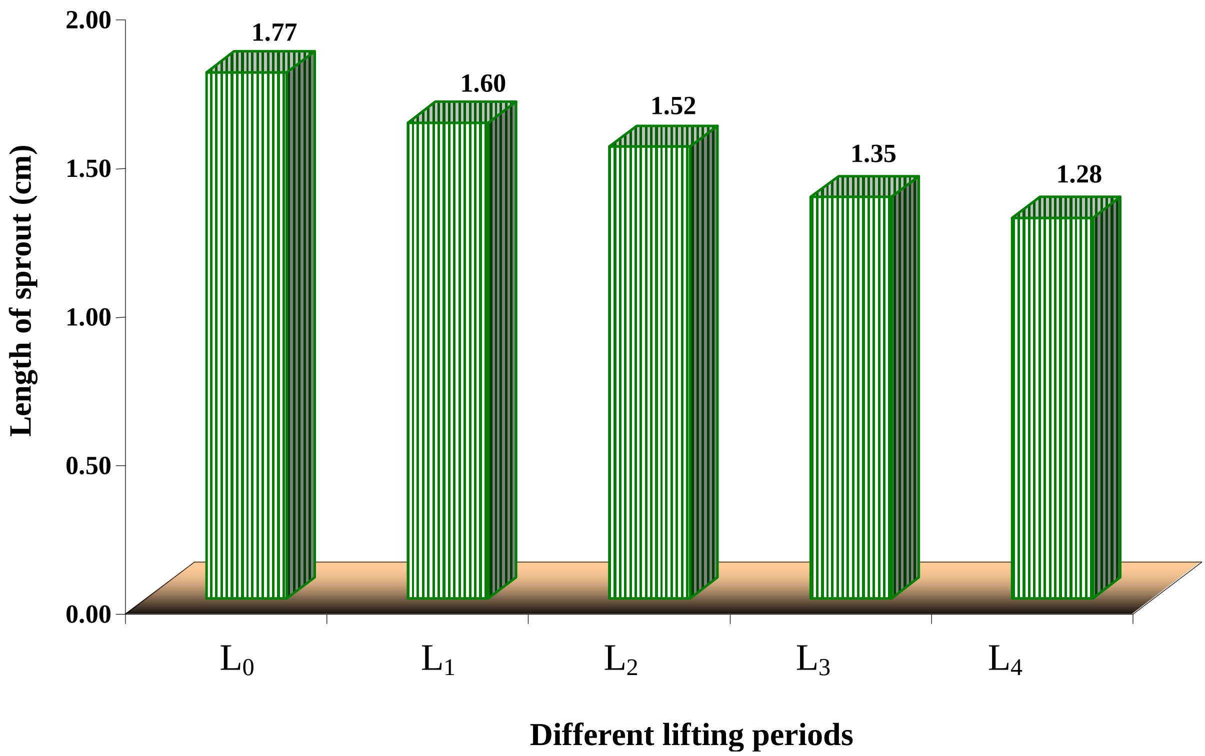

Fig. 1: Effect of length of sprout(cm)at different lifting period

4.5.2 Effect of tuber sized

Effect of sizes of tubers on length of sprout also showed significant difference at 1% level of probability on long term storage condition (Appendix V). The sprout length range was 1.42 to 1.60 cm on sizes of tubers where the longest (1.60 cm) was found from large size tubers and the shortest (1.42 cm) was taken from small size tuber at 120 DAS. However medium size tuber (1.50 cm) produced the average performance on length of sprout (Fig. 2). Similar trend of result were also reported by Roy et al. (2005) .

4.5.3 Combined effect of lifting period and sizes of tubers

Length of sprout significantly influenced by the combined effect of lifting period and sizes of tuber (Appendix V). Significant variation data on length of sprout range was 1.20 to 1.96 cm. The longest sprout (1.96 cm) was found from the lifting period of 0 days after haulm killing (L_0) under larger sized tuber. In contrast, small sized tuber also produced the shortest sprout (1.20 cm) from the 12 days after haulm killing (Table 10). Early and long sprout showed the lowest dry matter content as well as the decrease storage period of potato. So, the shortest sprout gave the longest storage.

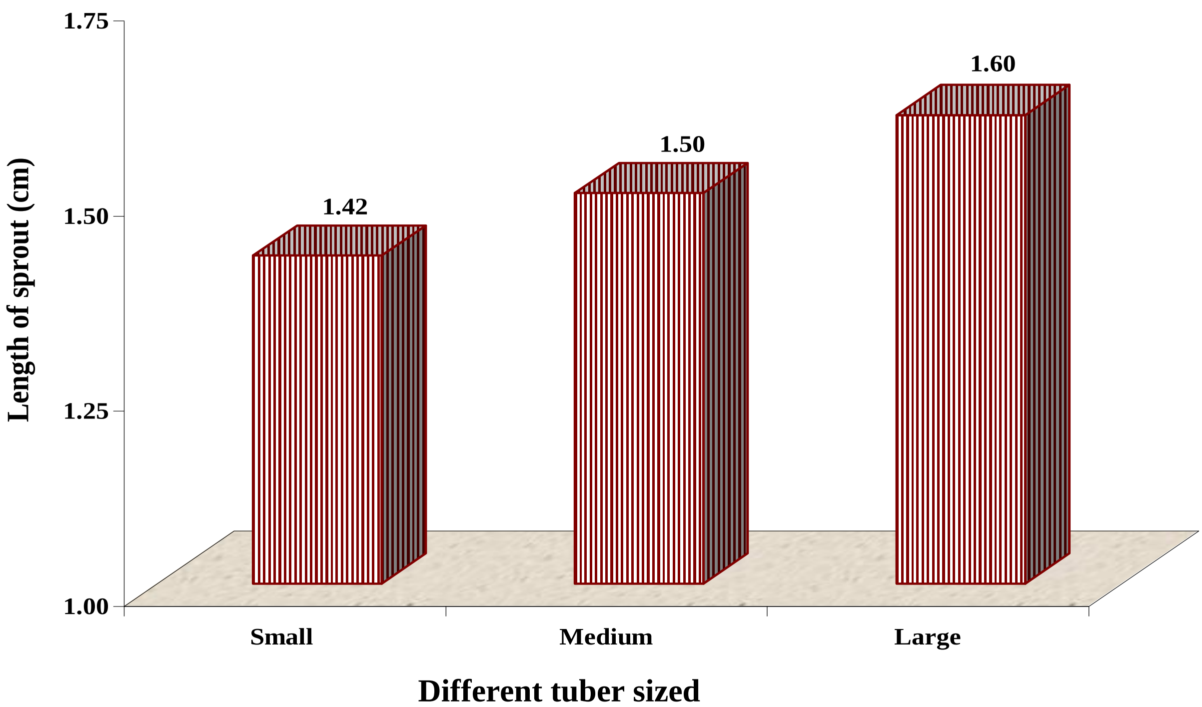

Fig. 2: Effect of length of sprout at different lifting period

4.6 Rotten tuber (%)

4.6.1 Effect of lifting period

Rotten tubers data showed significant differences among the lifting period at different days after storage (Appendix V). Among the lifting period, the minimum number of tuber rotten (1.79 and 2.13%) was taken from the lifting period of 9 days after haulm killing where the maximum number of rotten tuber (2.80 and 3.50%) was found at 0 days after haulm killing at 60 and 90 DAS, respectively. However, the minimum number of rotten tuber (2.20) was found at 12 days after haulm killing and it was statistically similar to 9 days after haulm killing at 120 DAS where the maximum number of rotten tubers (4.52) was found from the lifting period of 0 days after haulm killing at 120 DAS (fig.3). Among the storage period, maximum rotten tuber was recorded at final stage of data recording (120 DAS) because of increasing storage period increase the rotten tuber (fig.3).

4.6.2 Effect of tuber sized

Three sizes tubers, number of rotten tubers varied significantly over tuber sizes (Appendix V). Significant variation data at 60, 90 and 120 DAS was presented in Fig. 4. From the figure , it was found that the variation range was 2.04 to 2.60, 2.34 to 3.14 and 2.63 to 4.01 was taken from 60, 90 and 120 DAS, respectively (Fig. 4) where small sizes TPS produced the minimum number and larger tuber gave the maximum number of rotten tuber. However, medium sizes TPS produced the average results on rotten tuber at 60, 90 and 120 DAS, respectively. The present findings are in agreement with the reports of Small and Pahl (2012).

DAS= Days after storage
L_0= 0 days after haulm killing
L_1= 3 days after haulm killing
L_2= 6 days after haulm killing
L_3= 9 days after haulm killing
L_4= 12 days after haulm killing

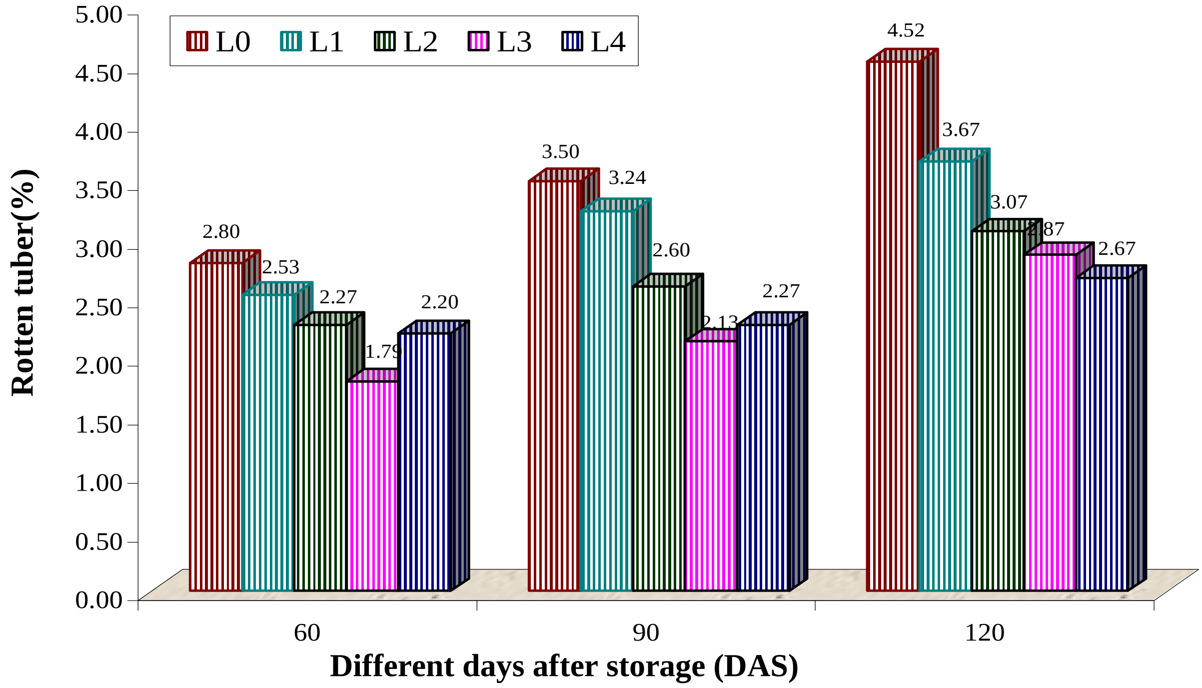

Fig. 3: Effect of lifting period on rotten tuber (%) at different days after storage

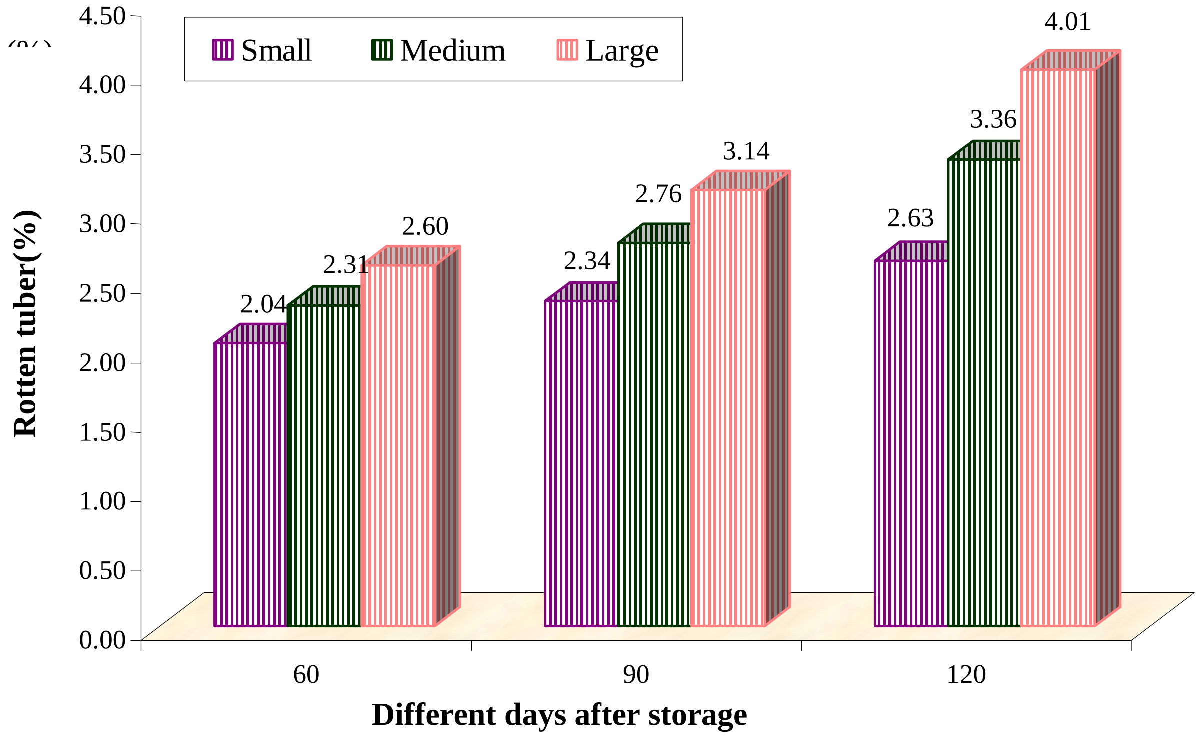

Fig. 4: Effect of tuber sized on rotten tuber (%) at different days after storage

4.6.3 Combined effect of lifting period and sizes of tubers

Number of rotten tubers was significantly affected by the combined effect of lifting period and sizes of tubers on natural storage period (Appendix V). The rotten tuber % data was recorded at 60, 90 and 120 days after storage and it was presented in Table10. From this table, it was observed that the lifting period of 0 days after haulm killing produced the maximum number of rotten tubers (3.20, 4.10and 5.70) at 60, 90 and 120 days after storage, respectively. However, the minimum number of rotten tuber (1.60) was found in small tuber of 9 days after haulm killing potato at 30 DAS. But at 90 and 120 DAS, the minimum number of tubers rotten (1.90 and 2.10) was observed in small tuber of 12 days after haulm killing storage potato which was statistically similar to 9 days after haulm killing potato at small sized tubers (1.90 and 2.20) at the similar DAS, respectively. Mature tuber perform the best than immature tuber in relation to rotten tuber in that case 0 days after haulm killing storage potato showed the maximum number of tuber rotten for its immature condition. Small tuber also showed better than larger tuber because of larger tuber very much affected by moisture to compare small tuber (Table 10).

Table 10: Combined effect of different lifting period and sizes on rotten tuber (%) at different days after storage

Lifting period	Sizes	Length of sprout (cm)	Rotten tuber(%) at different days after storage (DAS)		
			60	90	120
L_0	Small	1.62 b-d	2.40 de	2.90 cd	3.07 fg
	Medium	1.72 b	2.80 bc	3.50 ab	4.80 b
	Large	1.96 a	3.20 a	4.10 a	5.70 a
L_1	Small	1.54 b-e	1.99 g	2.71 c-e	3.0 f-h
	Medium	1.60 b-d	2.70 c	3.10 bc	3.70 de
	Large	1.67 bc	2.91 b	3.91 a	4.31 c
L_2	Small	1.48 c-f	2.00 g	2.30 d-f	2.80 gh
	Medium	1.52 c-f	2.30 ef	2.70 c-e	3.0 f-h
	Large	1.56 b-d	2.50 d	2.80 cd	3.40 ef
L_3	Small	1.24 h	1.60 i	1.90 f	2.20 i
	Medium	1.35 f-h	1.77 h	2.10 ef	2.50 hi
	Large	1.46 d-g	2.00 g	2.40 d-f	3.90 cd
L_4	Small	1.20 h	2.20 f	1.90 f	2.10 i
	Medium	1.28 gh	2.00 g	2.40 d-f	2.80 gh
	Large	1.36 e-h	2.40 de	2.50 c-f	3.10 fg
CV (%)		6.60	3.19	12.44	8.15
Level of Significance		**	**	**	**
SE		0.06	0.04	0.19	0.16

Different letter(s) within columns indicate significant difference by DMRT at 5% level of probability

DAS= Days after storage
L_0= 0 days after haulm killing
L_1= 3 days after haulm killing
L_2= 6 days after haulm killing
L_3= 9 days after haulm killing
L_4= 12 days after haulm killing

4.7 Total soluble solid (%)

4.7.1 Effect of lifting period

The differences among the lifting period in respect of total soluble solid at 60, 90 and 120 DAS showed significant at 1% level of probability (Appendix VI). Among the DAS, the highest TSS (5.99%) was observed from the lifting period of 9 days after haulm killing and it was closely followed by the 12 days after haulm killing (5.22%) at 60 DAS. However, lifting period of 0 days after haulm killing showed the minimum TSS (4.93%) at similar DAS. At 90 DAS, the highest TSS (6.74%) was found from the lifting period of 9 days after haulm killing and the lowest TSS (5.57%) was recorded from the lifting period of 0 days after haulm killing. On the other hand, the highest TSS (8.09%) was taken from the 9 days after haulm killing which was statistically followed by the L_2 or 6 days after haulm killing (7.66%) at 120 DAS. However, the lowest TSS (6.47%) was recorded from the lifting period of 12 days after haulm killing and it was also statistically similar to 0 days after haulm killing (6.57) (Table 11).

Table 11: Effect of lifting period on total soluble solid (%) at different days after storage

Lifting period	TSS (%)		
	60	90	120
L_0	4.93 c	5.57 c	6.57 c
L_1	5.03 bc	5.63 bc	7.03 bc
L_2	5.09 bc	5.86 b	7.66 ab
L_3	5.99 a	6.74 a	8.09 a
L_4	5.22 b	5.87 b	6.47 c
CV (%)	4.75	4.23	9.57
Level of Significance	**	**	**
SE	0.08	0.08	0.23

Different letter(s) within columns indicate significant difference by DMRT at 5% level of probability

DAS= Days after storage
L_0= 0 days after haulm killing
L_1= 3 days after haulm killing
L_2= 6 days after haulm killing
L_3= 9 days after haulm killing
L_4= 12 days after haulm killing

4.7.2 Effect of sizes of tubers

In case of tubers sizes, significantly the highest TSS (5.37%) was found from the small sizes TPS at 60 DAS where the lowest TSS (5.14%) was produced from the medium sizes TPS at 60 DAS. At 90 and 120 DAS, the highest (6.02 and 7.23%, respectively) was observed from the small sizes TPS where the all tubers produced the more or less similar results in case of they did not differ significantly. However, the lowest TSS (5.87 and 7.11%) was recorded from medium sized and larger tubers at 120 DAS, respectively (Table 12).Almost similar result was obtained by Molgard and Niekoal (1996).

Table 12: Effect of tuber sizes on total soluble solid (%) at different days after storage

Sizes	TSS (%)		
	60	**90**	**120**
Small	5.37 a	6.02 a	7.23 a
Medium	5.14 b	5.87 b	7.15 ab
Large	5.25 ab	5.92 ab	7.11 b
CV (%)	3.19	12.44	8.15
Level of Significance	**	ns	Ns
SE	0.06	0.07	0.18

Different letter(s) within columns indicate significant difference by DMRT at 5% level of probability
ns= Non Significant

4.7.3 Combined effect of lifting period and sizes of tubers

The analysis of variance for percent total soluble solid showed significant variation due to the effect between lifting period and tuber size at different days after storage (DAS) (Appendix VI). The TSS data was recorded at 60, 90 and 120 DAS where the variation range was 4.67 to 6.47%, 5.30 to 7.23% and 6.01 to 8.73%, respectively. Whereas, small sized tuber with the lifting period of 9 days after haulm killing showed the highest TSS (6.47, 7.23 and 8.73%) at 60, 90 and 120 DAS, respectively and it was closely followed by large sized tuber (5.83%) and medium sized tubers (6.57 and 8.13%) at 60, 90 and 120 DAS, respectively. In contrast, medium sized tubers with lifting period of 0 day after haulm killing storage potato showed the lowest TSS (4.67, 5.30 and 6.01%) at 60, 90 and 120 DAS, respectively (Table 13).

Table 13: Combined effect of different lifting period and tuber size on total soluble solid (%) at different days after storage

Lifting period	Sizes	TSS (%)		
		60	90	120
L_0	Small	5.40 b-d	5.93 de	6.63 cd
	Medium	4.67 g	5.30	6.01 d
	Large	4.73 fg	5.47e-g	7.06 b-d
L_1	Small	4.90 e-g	5.43 fg	6.97 b-d
	Medium	5.17 d-f	5.73 d-g	7.17 b-d
	Large	5.01 d-g	5.74 d-g	6.94 b-d
L_2	Small	5.00 d-g	5.84 d-f	7.33 b-d
	Medium	5.03 d-g	5.90 d-f	8.13 ab
	Large	5.23 c-e	5.83 d-f	7.53 a-c
L_3	Small	6.47 a	7.23 a	8.73 a
	Medium	5.67 bc	6.57 b	8.13 ab
	Large	5.83 b	6.43 bc	7.40 bc
L_4	Small	5.07 d-g	5.67 d-g	6.50 cd
	Medium	5.13 d-g	5.83 d-f	6.30 cd
	Large	5.47 b-d	6.10 cd	6.60 cd
CV (%)		4.75	4.23	9.57
Level of Significance		**	**	**
SE		0.14	0.15	0.40

DAS= Days after storage; L_0= 0 days after haulm killing; L_1= 3 days after haulm killing
L_2= 6 days after haulm killing; L_3= 9 days after haulm killing; L_4= 12 days after haulm killing

4.8 Days to sprout initiation

4.8.1 Effect of lifting period

Days to sprout initiation were significantly affected by the effect of different lifting period at 6 days after haulm killing (Appendix VII). Significant differences data in case of lifting period was presented in Figure 5. From this figure, the longer days (48.78 days) to sprouting was observed from the lifting period of 12 days after haulm killing which was closely followed by L_1 (48.03 days) and L_2 (47.22 days). The minimum days to sprout initiation (43.22 days) were recorded from the lifting period of 0 days after haulm killing. So, all the lifting period showed significant difference with L_4 .

DAS= Days after storage L_0= 0 days after haulm killing L_1= 3 days after haulm killing
L_2= 6 days after haulm killing L_3= 9 days after haulm killing L_4= 12 days after haulm killing

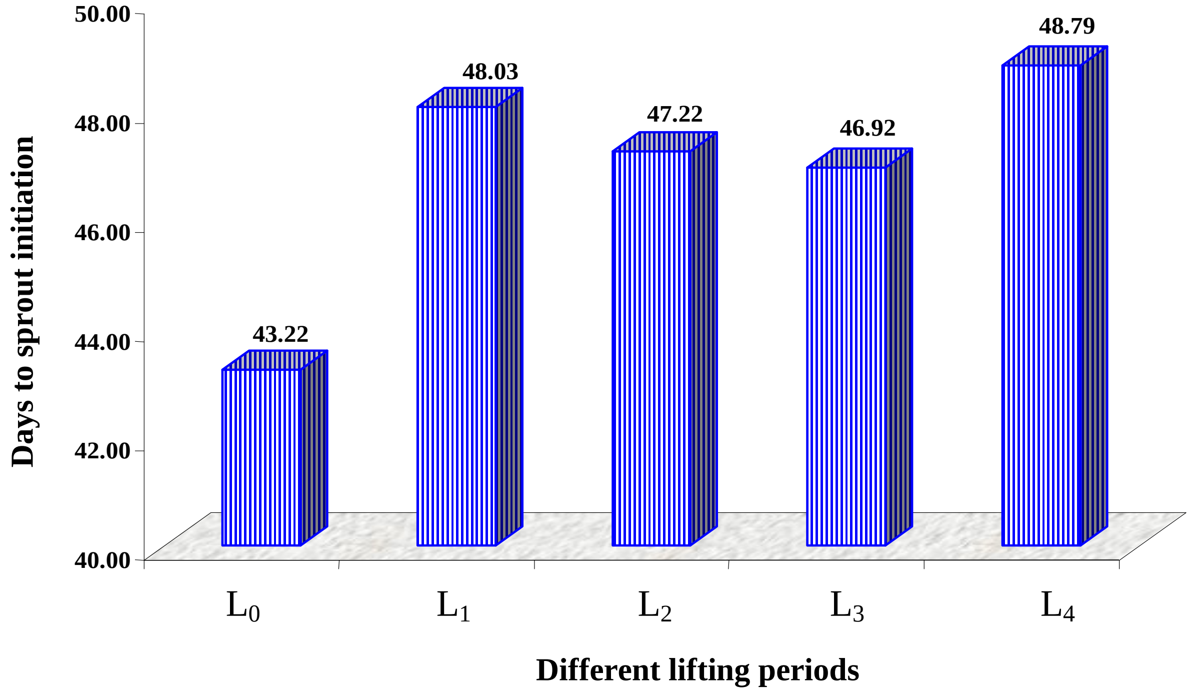

Fig. 5: Effect of lifting period on Days to sprout initiation of tubers at different days after storage

4.8.2 Effect of tuber sizes

Tuber sizes varied significant in respect of days to sprout initiation during storage period (Appendix VII). The longer days (56.01 days) to sprouting took by small sized tuber and the shorter days (37.08 days) to sprouting were found by larger TPS. Large tubers sprouted earlier than small and medium tubers in present study are in agreement with Hossain and Rashid (1991). Small sized tuber took longer days to sprouting which might be due to immaturity of tuber (Fig. 6).The result is in agreement with the findings of Hossain and Rashid(1991).

4.8.3 Combined effect of lifting period and sizes of tubers

Combined effect between lifting period and tuber sized significantly influenced on days to sprout initiation (Appendix VII). Significant variation range data on days to sprout initiation was 33.04 to 58.01 . The maximum days (58.01 days) to sprouting was found from the lifting period of 9 days after haulm killing (L_3) and it was statistically similar to 3, 6 and 12 days after haulm killing (56.33, 55.67 and 57.01 days, respectively) when the tuber size was small. Among the three sizes tuber, larger size tuber took minimum number of days (33.04 days) to sprouting with 9 days after haulm killing which was statistically similar (33.33) to control lifting period with larger tuber (Table 16).

DAS= Days after storage L_0= 0 days after haulm killing L_1= 3 days after haulm killing
L_2= 6 days after haulm killing L_3= 9 days after haulm killing L_4= 12 days after haulm killing

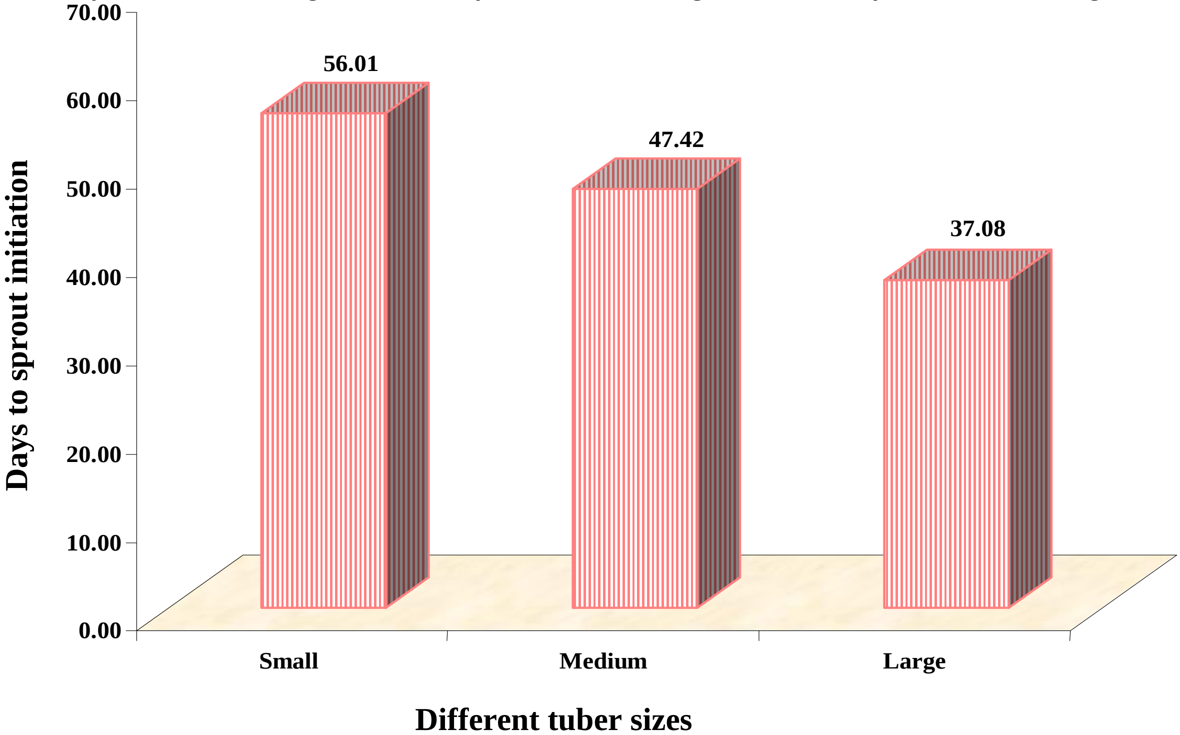

Fig. 6: Effect of sizes on days to sprout initiation at different days after tuber storage

4.9 Days to start shriveling

4.9.1 Effect of lifting period

The analysis of variance results on days to start shriveling of tubers did not vary significant variations among the lifting period at 3 days after interval (Appendix VII).

The maximum number of days (129.33 days) to start shriveling was observed from the lifting period of 12 days after haulm killing and it was statistically more or less similar to other lifting period in case of non significant affect was found on their results (Fig. 7). However, the minimum days to start shriveling (123.56 days) was noticed at the lifting period of 0 days after haulm killing .

4.9.2 Effect of tuber sizes

There were significant differences among tuber sizes in respect of days to start shriveling (Appendix VII). The maximum days to start shriveling (133.14 days) were obtained in small size tubers and the minimum days were required (121.74 days) to start shriveling. Medium sized tubers took the medium days (124.60 days) to start shriveling and it was statistically. Close with small and larger tubers (Fig. 8). Similar trend was obtained by Roy *et al. (2006)*

DAS= Days after storage L_0= 0 days after haulm killing L_1= 3 days after haulm killing
L_2= 6 days after haulm killing L_3= 9 days after haulm killing L_4= 12 days after haulm killing

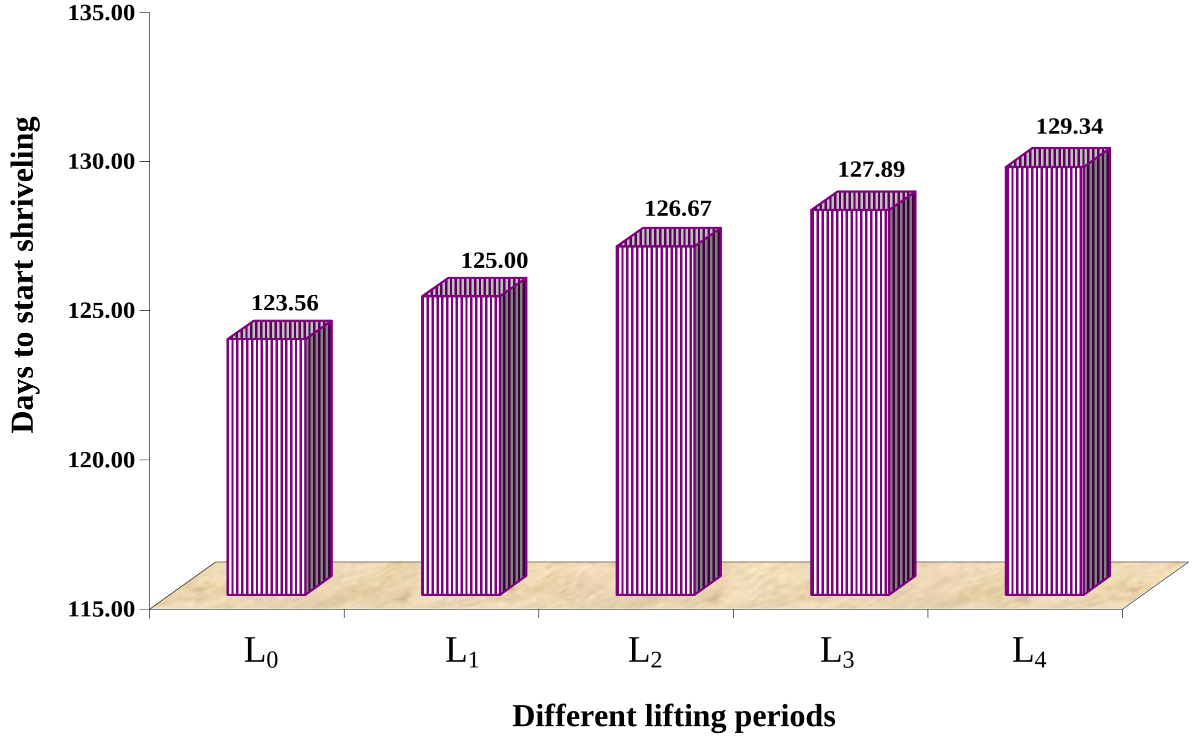

Fig. 7: Effect of lifting period on days to start shriveling at different days after storage

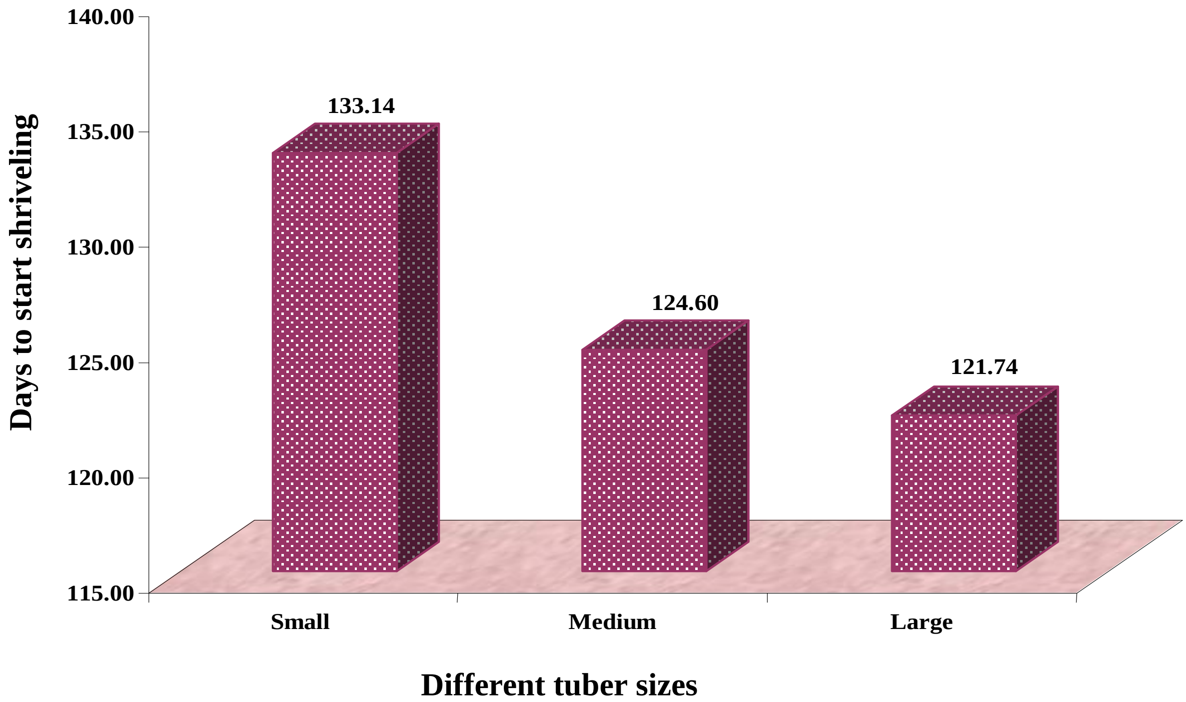

Fig. 8: Effect of tuber sizes on Days to start shriveling at different days after storage

4.9.3 Combined effect of lifting period and sizes of tubers

The differences among the combined effect between the lifting period and tuber sizes on days to start shriveling did not vary significantly (Appendix VII). Among the lifting period, 12 days after haulm killing requiring maximum number of days (136.00 days) to start shriveling but it did not differ significantly with 9 days after haulm killing lifting period (135.00). Larger tubers had the required lowest days (119.33 days) to start shriveling when the lifting period was 0 days after haulm killing (Table 16).

4.10 Days to 100% shriveling

4.10.1 Effect of lifting period

A non significant variation was found due to the combined effect between five lifting period and three tubers size in relation to days to 100% shriveling (Appendix VII). The results on the characters was presented in Table 14 where the maximum days to 100% shriveling (161.67 days) was exhibited by the lifting period of 12 days after haulm killing (L_2). However, lifting period of 0 days after haulm killing required the minimum number of days (154.47 days) to 100% shriveling. Among the another lifting period showed statistically identical results with each other in respect of requiring days to 100% shriveling (Table 14).

4.10.2 Effect of tuber size

The analysis of variance for days to 100% shriveling showed significant variations among the tuber sizes (Appendix VII). The maximum days were required to 100% shriveling (166.36 days) by small tubers size. The earlier 100% shriveling (152.16 days) was done by larger tuber than small and medium size tubers where medium size tubers need second maximum (155.62 days) days to 100% shriveling(Table 15). Early shriveling did not longer storage period and this result was agreed with Hossain *et al*. (1992b).

4.10.3 Combined effect of lifting period and tuber sized

In case of lifting period and tuber sizes, the maximum days to 100% shriveling (170.00 days) was required for small tuber size when the lifting period was 12 days after haulm killing which was statistically similar (168.4 days) with small tuber at 9 days after haulm killing. On the other hand, the minimum numbers of days were required (149.20 days) for 100% shriveling at 0 days after haulm killing storage potato with larger tuber (Table 16). More or less similar trend of shriveling behaviour has been documented by Singh (1980).

4.11 Apical sprout length (cm)

4.11.1 Effect of lifting period

Apical sprout length data was recorded at 120 days after storage, where the effect of lifting period did not vary significant (Appendix VII). However, the longest apical sprout (1.79 cm) was recorded from the lifting period of 0 day after haulm killing (L_0). On the other hand, the shortest apical sprout (1.27 cm) was obtained from the lifting period of 12 days after haulm killing (L_4) at 120 days after storage (Table 14)

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4.11.2 Effect of tuber sizes

Significant differences were observed due to the effect of tuber sizes in relation to apical length of sprout at 120 days after storage (Appendix VII and Table 15). The longest apical sprout (1.60 cm) was in larger tuber where small tuber showed the shortest apical sprout (1.42 cm) (Table 15).

4.11.3 Combined effect of lifting period and sizes of tubers

Combined effect between the lifting period and tubers sizes did not vary significant in relation to apical sprout length at 120 days after storage (Appendix VII). Apical sprout length of data range was 1.20 to 1.96 cm, where the longest apical sprout (1.96 cm) was found from the lifting period of 0 day after haulm killing when the tuber size was large. However, small tuber size also produced the shortest apical sprout (1.20 cm) when the lifting period was 12 days after haulm killing (Table 16).

Table 14: Effect of lifting period on tubers at different days after storage

Lifting period	Days to 100% shriveling	Apical sprout length (cm) at 120 DAS
L_0	154.47 b	1.79 a
L_1	156.14 ab	1.60 b
L_2	158.23 ab	1.52 c
L_3	159.73 ab	1.35 d
L_4	161.67 a	1.27 e
CV (%)	4.11	4.16
Level of Significance	**	**
SE	2.17	0.02

Different letter(s) within columns indicate significant difference by DMRT
DAS= Days after storage L_0= 0 days after haulm killing L_1= 3 days after haulm killing
L_2= 6 days after haulm killing L_3= 9 days after haulm killing L_4= 12 days after haulm killing

Table 15: Effect of sizes on tubers at different days after storage

Sizes	Days to 100% shriveling	Apical sprout length (cm) at120DAS
Small	166.36 a	1.42 c
Medium	155.62 b	1.51 b
Large	152.16 b	1.60 a
CV (%)	4.11	4.16
Level of Significance	**	**
SE	1.68	0.16

Different letter(s) within columns indicate significant difference by DMRT
DAS= Days after storage

Table 16: Combined effect of different lifting period and sizes on tubers at different days after storage

Lifting period	Sizes	Date of Sprout initiation	Days to 100% shriveling	Apical sprout length (cm) at 120DAS
L_0	Small	53.01 b	162.10 a-d	1.62 cd
	Medium	43.33 d	152.10 def	1.78 b
	Large	33.33 f	149.20 f	1.96 a
L_1	Small	56.33 a	164.60 a-d	1.54 d-f
	Medium	48.07 c	153.40 d-f	1.60 c-e
	Large	39.70 e	150.41 ef	1.67 c
L_2	Small	55.67 a	166.70 a-c	1.48 ef
	Medium	47.33 c	155.90 c-f	1.52 d-f
	Large	38.67 e	152.10 d-f	1.56 c-f
L_3	Small	58.01 a	168.40 ab	1.24 gh
	Medium	49.71 c	157.50 b-f	1.35 g
	Large	33.04 f	153.30 d-f	1.46 f
L_4	Small	57.01 a	170.00 a	1.20 h
	Medium	48.67 c	159.20 a-f	1.28 gh
	Large	40.67 e	155.80 c-f	1.33 g
CV (%)		3.34	4.11	4.16
Level of Significance		**	**	**
SE		0.62	1.68	0.163

Different letter(s) within columns indicate significant difference by DMRT

DAS= Days after storage L_0= 0 days after haulm killing L_1= 3 days after haulm killing
L_2= 6 days after haulm killing L_3= 9 days after haulm killing L_4= 12 days after haulm killing

From the investigation on the present study, it was found that the lifting period of 9 days after haulm killing (L_3) and small tubers (S) showed the superior results on the maximum postharvest characteristics of the study individually and combinedly. Significant extension of storage period was also recorded from the lifting period of 9 days after haulm killing in small tubers in case of minimum rotten tubers and weight loss percentage were recorded from these treatment combinations. On the other hand, lifting period of 9 and 12 days after haulm killing with small tubers took statistically maximum days to sprout initiation and 100% shriveling which will ensure the longer dormancy. So, storage period extension was occurred due to the treatment combination of L_3 and small tubers.

CHAPTER V

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

The present experiment investigated on natural storage performance of potato derived from true potato seed as affected by lifting period after haulm killing. The present study was conducted at the Laboratory of the Department of Agronomy, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka- 1207 during the period from 6^{th} March to 15 August, 2011. The experiment compared with 5 different lifting period viz., L_0 (0 day after haulm killing), L_1 (3 days after haulm killing), L_2 (6 days after haulm killing), L_3 (9 days after haulm killing) and L_4 (12 days after haulm killing) and three tuber sizes (small, medium and large) individual and combinedly. The experiment was laid out in a completely randomized design (CRD) with 3 replications.

In the main effect of lifting period showed significant difference on dry matter content of peel and flesh, weight loss, rotten tubers percentage, TSS, days to sprout initiation, days to start and 100% shriveling and apical length where the lifting period of 0 days after haulm killing (L_0) longest apical sprout length (1.79 cm) and shortest apical sprout (1.35 cm) was taken from 12 days after haulm killing. Similarly, 12 days after haulm killing produced the highest dry matter content of peel (21.44, 21.72, 22.90, 25 95 and 27.96%) where the lowest (14.51, 14.18, 17.84, 19.93 and 21.90%) was observed from 0 day after haulm killing at 0, 30, 90, 60 and 120 DAS, respectively. At 120 DAS, 0 day after haulm killing showed the highest (21.90%) and 0 day after haulm killing gave the lowest (14.18%) dry matter content of peel. Among the lifting period, dry matter content of flesh was the highest (21.44, 21.71, 22.90, 25.95 and 27.96%) at 12 days after haulm killing and the lowest (14.51, 14.17, 17.84, 19.93 and 21.90%) from 0 day after haulm killing at 0, 30, 60, 90 and 120 DAS, respectively. The minimum weight loss of tuber (5.53, 7.17, 8.03 and 15.27%) was also found from the 9 days after haulm killing and the maximum (6.87, 9.33, 11.87 and 18.07%) was taken from 0 day after haulm killing at 30, 60, 90 and 120 DAS, respectively. The longest sprout (1.77 cm) and the shortest sprout (1.28 cm) were observed from 0 and 12 days after haulm killing, respectively. In contrast, 0 days after haulm killing showed the maximum rotten tuber (2.80, 3.50 and 4.52%) at 60, 90 and 120 DAS, respectively where the minimum rotten tuber (1.79 and 2.13) was found at 60 and 90 DAS, respectively and 2.67 at 120 DAS. TSS was also found the best (5.9, 6.74 and 8.09%) with 9 days after haulm killing and the lowest (4.93, 5.57 and 6.57%) with 0 day after haulm killing at 60, 90 and 120 DAS, respectively. Sprout initiation, days to start and 100% shriveling was requiring the maximum (48.79, 129.34 and 161.67 days) when the lifting period was 12 days after haulm killing. However, 0 day after haulm killing gave the minimum requiring time (43.22, 123.56 and 154.47 days) for sprout initiation, days to start and 100% shriveling, respectively. Main effect of tuber sizes showed significant variation among the all characteristics except TSS at 90 and 120 DAS where they did not vary significant. Among the tuber sizes, small sized tuber produced the highest TSS (5.37, 6.02 and 7.23%) at 60, 90 and 120 DAS, respectively, sprout initiation (56.01 days), days to start and 100% shriveling (133.14 and 166.36 days, respectively). Similar tuber size also showed the lowest dry matter weight of peel (16.51, 16.64, 20.20 and 22.66%) and at 0, 30,60, 90 and 120 DAS, respectively, flesh (15.33, 15.89, 17.24, 18.59 and 21.35%) at 0, 30, 60, 90 and 120 DAS, respectively. The minimum weight loss (7.24, 8.50 and 15.70%) and rotten tubers (2.04, 2.34 and 2.63) were also produced by the small tuber at 60, 90 and 120 DAS, respectively. Length of apical sprout was the minimum (1.42 and 1.42 cm, respectively) with small tuber. Larger tuber also gave the longest sprout (1.60 cm), the minimum time (37.08 days) for sprout initiation, days to start and 100% shriveling (121.74 and 152.16 days, respectively) and the longest apical sprout (1.60 cm). Similarly, the highest dry matter content of peel (20.18, 20.36, 15.11, 24.04 and 26.53%), flesh (18.50, 19.15, 21.74, 23.18 and 25.60%) was recorded at 0, 30, 60, 90 and 120 DAS, respectively. The maximum weight loss (6.92, 8.88, 10.01 and 17.66%) was noticed in larger tuber at 30, 60, 90 and 120 DAS, respectively when the similar tuber also showed the maximum rotten tuber (2.60, 3.14 and 4.08%) was found at 60, 90 and 120 DAS, respectively. The minimum TSS (5.14 and 5.87%) was found with medium tuber at 60 and 90 DAS, respectively and larger tuber (7.11%) at 120 DAS.

The combined effect between 5 lifting periods and 3 tuber sizes showed significant difference among the all parameters where larger tuber also produced the highest dry matter content of peel (23.10, 23.43, 27.11 and 29.20%) and flesh (22.05, 22.94, 26.89 and 28.73%) were recorded from 12 days after haulm killing (L_4) where at 60 DAS the highest dry matter weight of peel (33.02%) was found in larger tuber of 0 day after haulm killing and flesh (24.70%) was obtained in larger tuber of 12 days after haulm killing. Small tuber of 0 day after haulm killing gave the lowest dry matter content of peel (12.90, 12.15, 14.47, 15.71 and 18.00%) and flesh (11.18, 11.98, 13.24, 14.47 and 16.29%) at 0, 30, 60, 90 and 120 DAS, respectively. Larger tuber also gave the maximum weight loss at 30 and 120 DAS (7.40 and 19.40%, respectively) with the 12 days after haulm killing and at 60 and 90 DAS (9.70 and 13.01%, respectively) with the 0 day after haulm killing. Similarly, small tuber of 12 days after haulm killing took the minimum weight loss at 30 DAS (4.80%) and small tuber of 9 days after haulm killing at 60, 90 and 120 DAS (5.9, 7.70 and 13.70%, respectively). Length of apical sprout produced the similar highest results (1.96 cm) and the lowest results (1.20 cm) with larger tuber of 0 day after haulm killing and small tuber of 12 days after haulm killing, respectively. Rotten tuber also produced the highest (3.20, 4.10 and 5.70) in larger tuber of 0 day after haulm killing at 60, 90 and 120 DAS, respectively and the lowest (1.60) was recorded in small tuber of 9 days after haulm killing at 30 DAS. Small tuber also showed the lowest (1.90 and 2.10) with 12 days after haulm killing at 90 and 120 DAS, respectively. Small tuber of the lifting period of 9 days after haulm killing (L_3) also formed the maximum TSS (6.47, 7.23 and 8.73%) and medium tuber of 0 day after haulm killing gave the minimum TSS (4.67, 5.30 and 6.01%) at 60, 90 and 120 DAS, respectively. Small tuber of 9 days after haulm killing took the longer time for sprout initiation (58.01 days) and small tuber of 12 days after haulm killing for days to start and 100% shriveling (136.00 and 170.00 days, respectively) where larger tuber of 12 days after haulm killing requiring the minimum time for sprout initiation (33.04 days) and larger tuber of 0 day after haulm killing for days to start and 100% shriveling (119.33 and 149.20 days, respectively)

Above results showed that the lifting period of 9 days after haulm killing (L_3) and small tubers exhibited better performance on weight loss and TSS to compare other lifting periods. Lifting period of 9 days after haulm killing also perform better on another parameters viz., sprout initiation, days to start and 100% shriveling etc. Similarly, small tuber also showed superior performance on whole assigned parameter in this study than other tubers size. Their combined effect showed greater results. So, significant extension of storage period was also recorded from the lifting period of 9 days after haulm killing in small tubers in case of minimum rotten tubers and weight loss percentage were recorded from these treatment combinations which will ensure the longer dormancy. So, storage period extension was occurred due to the treatment combination of 9 days after haulm killig and small tubers.

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APPENDICES

Appendix I: Monthly temperature and relative humidity during the storage period from 6 March to 15 August, 2011

Day	Room Temperature (^0C)		Relative Humidity
	Minimum	Maximum	(%)
March	24.2	26.4	**68**
April	26.6	31.2	71
May	32.5	36.7	75
June	35.1	38.5	77
Mean	**26.8**	**33.2**	**72.75**

Appendix II: Mean square of dry matter (%) of peel of tuber at different days after storage

Source	Degrees of Freedom	Initial weight of tuber/plot	Mean square of dry matter (%) of peel of potato at different days after storage				
			0	30	60	90	120
Factor A	4	116359.1	77.80**	87.00**	296.32**	108.70**	101.88**
Factor B	2	364124.3	51.69**	53.23**	10.98**	55.32**	58.13**
AB	8	28376.24	0.74**	0.58**	90.99**	1.76**	3.29**
Error	30	251.76	0.56	0.47	0.52	0.52	0.80

**= Significant at 1% level of probability

Appendix III: Mean square of dry matter (%) of flesh of tuber at different days after storage

Source	Degrees of Freedom	Mean square of dry matter weight (%) of flesh of potato at different days after storage				
		0	**30**	**60**	**90**	**120**
Factor A	4	89.53**	91.21**	71.26**	106.14**	114.38**
Factor B	2	38.54**	40.14**	77.70**	79.17**	68.91**
AB	8	0.31**	0.37**	0.94**	1.65**	4.44**
Error	30	0.51	0.52	0.48	0.51	0.51

**= Significant at 1% level of probability

Appendix IV: Mean square of weight loss of tuber (%) at different days after storage

Source	Degrees of Freedom	Mean square of weight loss of tuber (%)at different days after storage			
		30	**60**	**90**	**120**
Factor A	4	2.47**	5.63**	21.39**	12.43**
Factor B	2	8.13**	10.09**	8.67**	14.42**
AB	8	0.62**	0.49**	0.70**	2.16**
Error	30	0.49	0.50	0.50	0.50

**= Significant at 1% level of probability

Appendix V: Mean square of rotten tuber (%) at different days after storage

Source	Degrees of Freedom	Mean square of			
		Length of sprout (cm)	Rotten tuber(%) at different days after storage (DAS)		
			60	90	120
Factor A	4	0.34**	1.29**	3.23**	5.07**
Factor B	2	0.13**	1.19**	2.40**	7.86**
AB	8	0.01**	0.10**	0.13**	0.58**
Error	30	0.01	0.01	0.12	0.08

**= Significant at 1% level of probability

Appendix VI: Mean square of TSS (%) at different days after storage

Source	Degrees of Freedom	Mean square of TSS (%) at different days after storage (DAS)		
		60	90	120
Factor A	4	1.63**	2.01**	4.42**
Factor B	2	0.22**	0.09ns	0.06ns
AB	8	0.27**	0.25**	0.70**
Error	30	0.06	0.06	0.47

**= Significant at 1% level of probability and ns= non significant

Appendix VII: Mean square of sprout initiation, days to start and 100% shriveling and apical length at 120 DAS

Source	Degrees of Freedom	Mean square of			
		Sprout initiation	Days to start shriveling	Days to 100% shriveling	Apical sprout length (cm)at 120 DAS
Factor A	4	41.50**	47.033ns	73.05**	0.38**
Factor B	2	1346.79**	527.45**	822.39**	0.12**
AB	8	13.33**	0.43**	0.58**	0.01**
Error	30	2.45	34.51	42.26	0.00

**= Significant at 1% level of probability and ns= non significant