INFLUENCE OF VARIETY AND DATE OF HARVESTING ON POST HARVEST PHYSIOLOGY OF POTATO DERIVED FROM TPS AT AMBIENT STORAGE CONDITION

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DEDICATED
TO
MY BELOVED PARENTS

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CERTIFICATE

This is to certify that the thesis entitled **"Influence of Variety and Date of Harvesting on Post Harvest Physiology of Potato Derived from TPS at Ambient Storage Condition"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science** in **Agronomy**, embodies the result of a piece of bonafide research work carried out by **Apurbo Bhattacharjee**, Registration number: **06-01884** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has duly been acknowledged.

Dated:
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INFLUENCE OF VARIETY AND DATE OF HARVESTING ON POST HARVEST PHYSIOLOGY OF POTATO DERIVED FROM TPS AT AMBIENT STORAGE CONDITION

ABSTRACT

The experiment was conducted at Laboratory of Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during March to August 2012 to study the influence of variety and date of harvesting on post harvest physiology of potato derived from TPS at ambient storage condition. The experiment consisted of 2 factors: Factor A: Potato variety (4 varieties) as- V_1: BARI TPS-1, V_2: BARI TPS-2, V_3: HPS-364/67 and V_4: Lady Rosetta; Factor B: Time of harvest (4 times) as- D_1: 80 DAP, D_2: 90 DAP, D_3: 100 DAP and D_4: 110 DAP. Potato variety and time of harvest had significant effect on all post harvest physiological parameters and nutritional aspects. Dry matter content, weight loss and percentage of rotten tubers increased with advancing storage period irrespective of varieties. Among varieties BARI TPS-1 was superior to those of others. All post harvest losses except apical sprout length decreased with increasing the time of harvest. Specific gravity, reducing sugar, total sugar and starch content increased with advancing storage period, whereas non-reducing sugar decreased with increasing storage period. Among the varieties HPS 364/67 was the best in respect of nutritional aspects. Due to the interaction effect of different variety and time of harvest at before storage and 20, 40, 60, 80, 100 DAS, the highest maximum dry matter in flesh (13.99, 17.75, 18.80, 19.93, 21.71 and 22.57%) was observed from V_1D_4 and the lowest from V_1D_1. The highest days required for starting of sprouting (51.67) was observed from V_1D_3 and V_1D_4, while the minimum from V_4D_1. At harvest and 100 DAS, the highest total sugar (0.61% and 0.82%) was observed from V_4D_4, while the lowest total sugar from V_3D_1. The results revealed that BARI TPS-1 showed better storage quality. Physiological performance compared to those of other varieties when harvested at 100 days after planting, while HPS 364/67 showed superior nutritional quality than other varieties when harvested at the same days.

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CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a tuber crop belonging to the family Solanceae is one of the most important vegetable crops of the world. It is originated in the Peru-Bolivian region in the Andes of South America (Grewal *et al*., 1992). It is the 4th major crops of the world on the basis of production and consumption and used as a principal vegetable in most of the Asian countries (Rashid, 1987). In Bangladesh, potato is one of the major crops next to rice and wheat, and covers an area of about 403.4 thousand hectare of land producing 5.95 million tons of potato with 14.74 tons of average yield hectare^{-1} (MoA, 2009). Now a days potato is the third staple vegetable crop could contribute in poverty alleviation and food security in Bangladesh. It is a carbohydrate rich crop, and is consumed almost absolutely as a vegetable in Bangladesh. It contributes as much as 55% of the total vegetable demand in Bangladesh (BBS, 2011).

Potato is not only a vegetable crop but also an alternative food crop against rice and wheat. Nutritionally, the tuber is rich in carbohydrates or starch and is a good source of protein, vitamin C and B, potassium, phosphorus and iron. Most of the minerals and protein are concentrated in a thin layer beneath the skin, and skin itself is a source of food fibre. Bangladesh has a significant agro-ecological potential of growing potato. The area and production of potato in Bangladesh has been increasing during last decades but the yield per unit area remains more or less static. The yield is very low in comparison to that of the other leading potato growing countries of the world, 40.16 t ha^{-1} in USA, 42.1 t ha^{-1} in Denmark and 40.0 t ha^{-1} in UK (FAO, 2009). 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).

True Potato Seeds (TPS) is sexual seed of potato crop, which is produced through open pollination as well as artificial pollination for producing hybrid seeds in between two known parents as male and female. Recently, the use of TPS for the production of high quality seed potatoes has been well established as an acceptable technology instead of tuber seeds in many countries including Bangladesh. The use of TPS for potato production has increased recently in Europe, North America and Asia, especially in the developing countries (Burton, 1989; Devaux, 1984; Wiersema and Cabello, 1987). This is due to low transmission of disease, high multiplication rate and good tuber yield (Siddique and Rashid, 2000). 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 harvesting period for keeping quality under storage condition is not sufficient in our country. But the information of the ambient storage and its mechanism is of great importance for the selection of TPS progenies having good keeping quality.

Usually, 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. Harvesting period can play important role on natural storage of potato. In Bangladesh, potato is generally stored in three ways, namely (i) in cold stores under controlled environment (ii) in the houses under controlled environment and (iii) in the houses under ordinary room conditions. In Bangladesh, the present cold storage capacity is only about 25% of the total potato productions (BBS, 2010). An important characteristic of potato varieties is that, they can be stored under ordinary room conditions for a relative longer period. Naturally the potato varieties are more convenient for those growers who wish to store their own produce for consumption and scale over a long period under ordinary room conditions and for use as table potatoes. Knowledge of proper storage environment obviously helps to maintain the quality, extend the storage period and increases the value of stored potato.

In Bangladesh, the use of TPS for potato production has increased recently but very few reports are available regarding different TPS variety and their lifting period which can play an important role on natural storage of potato. The purpose of the present research is to provide the information on lifting period for different TPS variety under natural storage condition to meet the produced demand.

In the context of the mentioned above situation the present piece of research work was undertaken with following objectives-

- To find out the suitable TPS variety for longer storage dormancy under ambient condition
- To find out the suitable time of harvest for better keeping quality under natural condition, and
- To study the quality assessment of some TPS variety and non-TPS cultivar (Lady Rosetta) under natural storage condition.

CHAPTER II

REVIEW OF LITERATURE

Potato is one of the most important vegetable crops in Bangladesh and storage facilities are also a serious problem due to lack of appropriate storage facilities and transport. In Bangladesh, potato is generally stored in three ways, namely (i) in cold stores under controlled environment (ii) in the houses under controlled environment and (iii) in the houses under ordinary room conditions. But the present cold storage capacity is only about 25% of the total potato production which is not sufficient as per demand. For better storage it is necessary to know the lifting time for different TPS variety for natural storage condition. Very limited research reports on the performance of TPS variety in different days after harvest in natural storage condition have been done in various part of the world including Bangladesh and the work so far done in Bangladesh is not adequate and conclusive. However, some of the important and informative works conducted at home and abroad in this aspect reviewed here under the following headings:

2.1 Varietal performance on storage of potato

Schwarz and Geisel (2012) reported that 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.

Storability of tubers obtained from 9 hybrid True Potato Seed (TPS) progenies were compared with that of non-TPS cultivar ‘Diamant’ under ambient conditions (22.0-34.80C 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 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.

The effects of farmyard manure, straw + 45:45:90 kg NPK/ha, 90:90:180 kg NPK/ha, and 90:90:180 kg NPK + micronutrients on the yield, and starch and dry matter contents of early (Goda and Voke), moderately early (Lady Rosetta) and moderately late (Saturna and Heres) potato cultivars were studied by Rainys and Rudokas (2005) in Lithuania. Tuber yield was significantly affected by the fertilizers, genotype and weather conditions. The growing period and cultivar had significant effects on starch and dry matter contents of tubers. Averaged over the 3 years, the highest starch and dry matter contents were recorded for Lady Rosetta (17.0-17.9 and 23.2-24.1%) and Saturna (17.1-17.4 and 23.5-23.8%). The cultivars had the highest starch and dry matter contents in 2002 (14.9-21.0 and 21.3-27.1%).

Madalageri (1999) studies on tuber uniformity and storage behaviour of 7 TPS progenies (hybrids and open pollinated progenies) in comparison with tuber planted cultivars revealed that the TPS progenies were as good as those of tuber planted crops in respect of physiological loss in weight, and frequency and weight of rotten and sprouted tubers after 3 months of storage under ambient conditions. However, only hybrid populations HPS I/13, HPS II/13 and TPS-C-3 had comparable scores with the tuber planted standard varieties in respect of tuber uniformity. The produce from open pollinated TPS families recorded significantly lower uniformity scores than their counterpart hybrid populations or the tuber planted standard varieties.

Storage behavior 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 effect on tuber yield was also examined in one experiment. The storage regimes were: 18^0C continuously, hot pre-treatments of different duration (different periods at 28^0C and subsequently 18^0C) and a cold pre-treatment (20 days at 2^0C and subsequently 18^0C). Both a foliar spray with GA and storage at 28^0C 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 Desiree 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 *Fusariun* 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 potato 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 accelerates 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 and seed potatoes cm 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 were 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 varies (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 included weight losses of tubers due to vital process of tubers (respiration, evaporation, sprouting) and those resulting from parasites and pathogenic micro flora. 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 15.6^0C and 90% RH for up to a year. The total weight loss of six cultivars was 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 (0-15^0C, 15-75% RH) or a stire house (15-18^0C, 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 gave 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 Harvest period performance of storage potato

Chang *et al*. (2005) to investigate the growth patterns of this cultivar, including tuber number, size and quality, under hydroponics, potato tubers were sampled at 60, 70, 80 and 90 days after transplanting (DAT). Specific gravity increased with the tuber size up to 10 g, but the difference between 10 and 50 g tubers was not significant. The specific gravity increased over time to 90 DAT. Shoot growth was maximum at the early harvesting date (60 or 70 DAT) and declined thereafter. Except for tubers from 60 DAT, the dormant period of early harvest tubers was not different with that of late harvest tubers of 90 DAT. These results clearly represented an economic advantage of early harvesting of 70 or 80 DAT because of cost reduction in hydroponics.

A field study was conducted by Tamiru (2005) involving potato varieties Al-111 and Al-624 with four population densities (88 888, 66 666, 44 444 and 33 333 plants/ha) and three harvesting times (70, 90 and 110 days after planting) to determine their influence on growth and dry matter production at Rarie, Alemanya University during the main season of 2000. High plant population significantly increased plant height but reduced number of branches, number of leaves, and

haulm fresh and dry weights on per plant basis. Highly significant increase in tuber dry matter yield was recorded with increased plant population and delayed harvesting. A plant population of about 88,888 plants/ha and harvesting at 90th day after planting (DAP) promoted production of maximum dry matter yield per unit area, irrespective of varieties studied.

Tuber yield, processing quality and changes in the processing and nutritional characteristics, such as dry matter, reducing sugars, sucrose, soluble protein, free amino acids and total phenols, were investigated by Marwaha *et al*. (2005) in the tubers of five Indian potato varieties including two processing and three table varieties and five American processing cultivars. Samples were harvested at 10-day intervals commencing on 13 December, 60 days after planting, till 90 days. The 90-day-old-crop (mature) was then defoliated or dehaulmed and tuber samples were harvested after 20 days of tuber skin-curing in the soil under short day conditions (Min. 3.9-21.0^{0}C, Max. 10.6-31.7^{0}C, day length 11.5-9.75 hr). After harvest, changes were also determined in the tubers during pre-storage holding period and up to 90 days of storage in an evaporatively-cooled store at high temperature (Min. 14.5-24^{0}C, Max. 24-31^{0}C, RH 71-95%) and in the cold store (3-4 degrees C, RH 95-98%), followed by reconditioning of tubers stored in the cold store. Yield increased significantly up to the last date of harvest and the mature tubers displayed significantly higher dry matter, free amino acids and total phenols but lower levels of reducing sugars and sucrose and produced chips with better colour appearance. Skin curing of the mature tubers for 20 days in the soil, darkened the chip colour with increase in the mean reducing sugars, free amino acids and soluble protein and reduction in sucrose and total phenols with no significant change in dry matter content of tubers. Both the Indian processing cultivars viz. Kufri Chipsona-1 and Kufri Chipsona-2 and all the five exotic cultivars viz. Atlantic, FL 1291, FL 1533, FL 1584 and FL 1625, stored in the evaporatively cooled store at high temperature up to 90 days, produced chips of acceptable colour. Conversely, tubers of all the cultivars stored in the cold store even after 45 days, produced unacceptably dark coloured chips with tremendous

increase in reducing sugars. Reconditioning the cold stored tubers after 45 and 90 days of storage for 3 weeks at 20^0C reduced the mean reducing sugar content by 30 and 41% respectively, but did not bring desirable change in chip colour. Cultivars processed after 90 days of storage in the evaporatively cooled store gave lower chip yields with higher oil contents as compared to initial storage. The results revealed that both Indian and exotic processing cultivars which contained average reducing sugars <0.15% on fresh tuber weight during pre-harvest stage generally produced chips of acceptable colour during different harvests as well as during storage up to 90 days in an evaporatively cooled store with total tuber weight losses between 8.5-12.5%.

An experiment was conducted by Bashir *et al*. (2005) in Pakistan, to determine the effect of altitude (in Parachinar at 1959 m and in Sultan at 1424 m above sea level) and harvesting date (80, 90, 100 and 110 days after planting) on the yield and quality of seed potato (cv. Desiree). The earliest days to 50% emergence and days to 80% emergence was obtained with potatoes planted in Sultan while those in Parachinar gave the highest emergence percentage, plant height, ground coverage, number of stems per plant and mean total yield. Comparative data on the weight of small-sized tubers per plot, weight of medium-sized tubers per plot, weight of large-sized tubers per plot, seed potato yield per hectare and sprouting percentage of seed potato tubers as influenced by altitude and harvesting date are tabulated.

In order to select cultivars suitable for processing and determine the optimum harvesting time for the potato cultivars suitable for cultivation in Korea, potato tubers from six cultivars were harvested 80, 90, 100 and 110 days after planting, and the processing quality parameters were investigated by Jeong *et al*. (1996). All cultivars showed a gradual increase in specific gravity, dry matter content and starch content until 100 days after planting, and showed a decrease thereafter. Reducing sugar content showed the reverse tendency of changes. In spite of the slight difference among cultivars, the highest crisp colour value was obtained 90 to 100 days after planting. Among six cultivars tested, cv. Atlantic and Superior

showed a higher processing quality than other cultivars, and Dejima showed the lowest quality.

A study was conducted by Kim *et al*. (1998) in Cheju, Korea, to investigate the relationship between harvesting date and deterioration rate, sprouting rate and the sugar, protein and ascorbic acid contents of potato cv. Dejima, Gosi#1 and Gosi#5 tubers. Potatoes were harvested 90, 120, 150, 180, 210 or 240 days after planting. No differences in deterioration rate and sprouting rate were observed between cultivars, but these factors increased when tubers were harvested 180, 210 or 240 days after planting. Gosi#1 exhibited the lowest yield per 10 a. Total sugar and crude protein contents remained constant until 180 days after planting, but reduced thereafter, total sugar and crude protein content at 240 days after planting being reduced by 3% and 0.2% compared to that at 90 days. Vitamin C content was reduced by 3-4 mg at 240 days after planting. Mineral composition (Ca, P, K, Fe) exhibited a tendency to be reduced when the harvesting time was delayed. It is suggested that until 210.

2.3 Storage behavior on physiological and chemical changes of potato

The effects of variety, tuber group, storage period and storage type on glycoalkaloid levels of potato tubers and sprouts were investigated by Sengul *et al*. (2004). Normal, wounded and greened tubers and sprouts from potatoes of varieties Marfona and Granola were analysed for alpha -solanine, alpha -chaconine and total glycoalkaloid concentration by using HPLC. The potatoes were stored in normal store light, normal store dark, retail refrigerator light, and retail refrigerator dark. Analyses were carried out at the beginning, 3rd and 6th months for the potatoes, and at 6th month for the sprouts. The tubers had an alpha -solanine content ranging from 0.01 to 6.46 mg/kg FW, alpha -chaconine content from 0.35 to 28.12 mg/kg FW and total glycoalkaloid content from 0.66 to 32.76 mg/kg FW.

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.

A field experiment was conducted by Lalitha *et al*. (2000) in Karnataka, India to investigate the effects of K (100, 125 and 150 kg/ha) and S levels (0 and 25 kg/ha) on the yield and quality of potato raised from seed tubers (cv. Kufri Jyothi) and true potato seeds (HPS-1/13). Starch and crude protein contents were higher in HPS-1/13 than in Kufri Jyothi, but Kufri Jyothi showed higher harvest index and bulking rate. K at 125 kg/ha and S at 25 kg/ha resulted in the highest starch (73.56%) and crude protein content (12.73%). Combination of K + S at 125 + 25 kg/ha and 150 + 25 kg/ha produced the highest tuber yield (22.15 and 22.24 t/ha, respectively), size of high grade tubers, harvest index and bulking rate. K + S at 150 + 25 kg/ha resulted in the highest net returns.

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 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 behavior 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-spouting 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.

Khan *et al*. (1984) reported 40.6% tuber loss in natural storage. 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

The experiment was conducted during the period from March to August 2012 to study the influence of variety and date of harvesting on post harvest physiology of potato derived from TPS at ambient storage condition. The materials and methods describes a short description of the experimental site, climate condition of the storage room, experimental materials, experimental treatments and design, methods of the study, data collection procedure and procedure of data analysis. The detailed materials and methods that were used to conduct the study is presented below under the following heading:

3.1 Location of the experimental site

The experiment was conducted at the Laboratory of the Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. It was located in 24.09^0N latitude and 90.26^0E longitudes.

3.2 Conditions of storage room

The temperature and relative humidity of the storage room were recorded daily basis during the study period with a digital thermo hygrometer (TERMO, TFA, Germany). The minimum and maximum temperature during the study period of the storage room was 26.4^0C to 33.6^0C, respectively. The minimum and maximum relative humidity was 54% and 83%, respectively. Details of the meteorological data during the period of the experiment were presented in Appendix I.

3.3 Experimental materials

The tubers used for the experiment were BARI TPS-1, BARI TPS-2, HPS-364/67 and Lady Rosetta, and were collected at harvest from Sher-e-Bangla Agricultural University (SAU) farm. The collected tubers were free of any visible defects, disease symptoms and insect infestations and transported to the Laboratory of the Department of Agronomy, 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 harvesting period as affected by different variety/genotypes under quality observation. The potatoes were harvested as per the experimental requirements. The experiment consisted of 2 factors:

Factor A: Potato variety (4 varieties) as

i. V_1: BARI TPS-1

ii. V_2: BARI TPS-2

iii. V_3: HPS-364/67

iv. V_4: Lady Rosetta

Factor B: Time of harvest (4 times) as

i D_1: 80 DAP

ii. D_2: 90 DAP

iii. D_3: 100 DAP

iv. D_4: 110 DAP

As such there were 16 treatment combinations viz., V_1D_1, V_1D_2, V_1D_3, V_1D_4, V_2D_1, V_2D_2, V_2D_3, V_2D_4, V_3D_1, V_3D_2, V_3D_3, V_3D_4, V_4D_1, V_4D_2, V_4D_3 and V_4D_4.

The experiment was laid out in a 2 factors Completely Randomized Design (CRD) with 3 replications.

3.5 Methods of the study

There were 16 (4×4) treatment combinations of the collected potato tubers. Thirty tubers (10 for each replication) for specific treatment combination were selected for conducting the experiment. The selected tubers of each combination with 3 replications were kept in netted plastic basket and were stored in a well ventilated room under diffused light condition. Tubers were observed at every alternate day

for recording rotted tubers and sprouting. Weighing of tubers was continued upto 100 days after storage (DAS) at 20 days interval. For recording the data of 80% shriveling potato were stored upto the days of 80% shrivling although dry matter content and weight loss were estimated upto 100 days. Number of sprouts per tuber, length and weight of sprout and physical condition of tubers were recorded at 100 days. Physical condition of tubers was evaluated by eye estimation following an arbitrary scale (1= no shrinkage and 5= maximum shrinkage).

3.6 Parameter studies

The following parameters were studied and data were recorded following the procedure described below:

3.6.1 Dry matter of peel of potato

Fresh and dry weight percentage of peel (skin of potato) was recorded at 20, 40, 60, 80 and 100 DAS. Peel of potato was dried in oven at 72^0C for 72 hours and then the dry matter percentage of peel was recorded. Dry matter percentage of peel was also recorded on the basis of fresh weight.

$$\text{Dry matter} = 100- \times \frac{FW - DW}{FW} \times 100$$

Where, FW= Fresh weight and DW = Dry weight

3.6.2 Dry matter of flesh of potato

Dry matter percentage of flesh was recorded at 20, 40, 60, 80 and 100 DAS. Flesh of potato was also dried in oven at 72^0C for 72 hours and then the dry matter percentage of flesh was recorded. Dry matter percentage of flesh was also recorded on the basis of fresh weight.

3.6.3 Weight loss

Potato was stored as per treatment and their initial weight was taken. Weight loss percentage was recorded at 20, 40, 60, 80 and 100 DAS from the stored potato. Weight loss was calculated using the following formula:

Percent weight loss (%), $WL = \frac{IW - FW}{IW} \times 100$

Where,

WL = Percent total weight loss;

IW = Initial weight of tubers (g)

FW = Final weight of tubers (g)

3.6.4 Percentage of rotten tubers

After the harvest, potato was stored for 100 days. Rotten tuber percentage was determined at 20, 40, 60, 80 and 100 days after storage (DAS) by adding the data of every alternate day with eye observation.

3.6.5 Days to start of sprouting

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

3.6.6 Apical sprout length

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

3.6.7 Days to start of rottening

The tubers were keenly observed for tuber start of rottening. Rottening indicates physical condition of the tubers.

3.6.8 Days to start of shriveling

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

3.6.9 Days to 80% shriveling

The data were recorded for shriveling of 100% following arbitrary scale 1-5 (where 1= no shriveling and 5= maximum shriveling).

3.6.10 Chemical analysis

The estimation of starch and sugars was conducted by the laboratory of Bangladesh Scientific and Industrial Research Institute.

3.6.10.1 Determination of starch and sugar

Starch, reducing sugar, non-reducing sugar and total sugar were determined by Luff-schoorls method number 4 of International Federation of Fruit Juice Procedures (1985).

3.6.10.2 Specific gravity

Specific gravity was measured by using the following formula-

$$\text{Specific gravity} = \frac{\text{Weight in air}}{\text{Weight after imbibition in water}}$$

3.7 Statistical analysis

The data obtained for different characters were statistically analyzed to find out the significant difference of the recorded parameters for tubers derived from different variety of potato tubers and time of harvesting. The mean values of all the recorded characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment combinations of means was estimated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

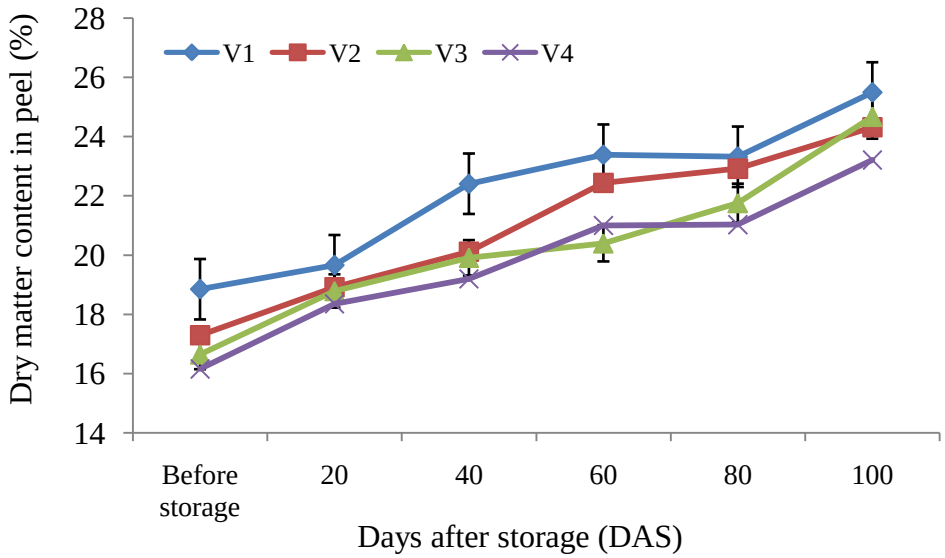
The experiment was conducted to study the influence of variety and date of harvesting on post harvest physiology of potato derived from TPS at ambient storage condition. Data were recorded at different days after storage (DAS) on different physical and chemical characteristics were recorded. The analyses of variance (ANOVA) of the data on different physical and chemical characteristics are presented in Appendix III-VIII. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Dry matter of peel

Significant statistical variation was recorded for dry matter content in peel of potato that derived from true potato seeds (TPS) variety along with Lady Rosetta at storage (Appendix II). At before storage and 20, 40, 60, 80, 100 DAS, the maximum dry matter in peel (18.85, 19.66, 22.41, 23.39, 23.32 and 25.49%) was recorded in V_1 (BARI TPS-1) which was statistically similar (17.30, 18.92, 20.12, 22.44, 22.92 and 24.32%) with V_2 (BARI TPS-2), whereas the lowest (16.16, 18.36, 19.20, 21.00, 21.03 and 23.21%) was observed from V_4 (Lady Rosetta) which was statistically similar (16.65, 18.79, 19.91, 20.40, 21.76 and 24.67%) to V_3 (HPS-364/67) (Figure 1). Generally good storage management will help to salvage problem tuber lots, but storage will never improve a poor quality variety. Data revealed that different variety exhibited different amount of dry matter content of peel at different days after storage in normal storage condition. Rainys and Rudokas (2005) recorded the highest dry matter contents of peel for Lady Rosetta (23.2-24.1%) and Saturna (23.5-23.8%).

Dry matter content in peel of potato showed statistically significant variation for different time of harvest (Appendix II). At before storage and 20, 40, 60, 80, 100 DAS, the highest dry matter in peel (19.78, 20.43, 23.52, 25.00, 25.45 and 26.13%) was observed from D_4 (harvest at 110 DAP) which was statistically similar (18.85, 20.30, 22.61, 23.48, 23.78 and 25.57%) to D_3 (harvest at 100 DAP) and followed (16.36, 19.01, 20.83, 21.32, 21.53 and 24.67%) by D_2 (harvest at 90 DAP), while the lowest (13.97, 15.99, 16.09, 17.43, 18.27 and 21.32%) was recorded in D_1 (harvest at 80 DAP) at same data recorded days (Figure 2). It was found that dry matter percentage increased with the increasing the time of harvest. Tamiru (2005) reported that 90th day after planting (DAP) promoted production of maximum dry matter yield per unit area, irrespective of varieties studied.

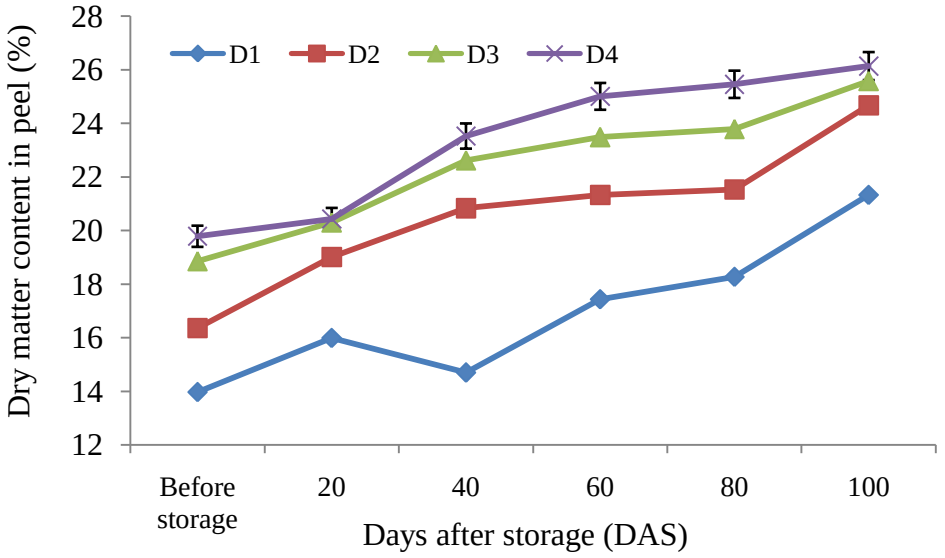
The combined effect of different variety and harvesting time was also significant for dry matter content in peel of potatoes (Appendix II). At before storage and 20, 40, 60, 80, 100 DAS, the highest dry matter in peel (23.30, 23.66, 26.71, 28.20, 28.80 and 28.60%) was observed from V_1D_4 (BARI TPS-1 and harvest at 110 DAP) and the lowest dry matter in peel (12.25, 14.16, 15.05, 15.50, 15.63 and 19.38%) was recorded from V_1D_1 (BARI TPS-1 and harvest at 80 DAP) at same data recorded days (Table 1).



V_1: BARI TPS-1 V_2: BARI TPS-2

V_3: HPS-364/67 V_4: Lady Rosetta

Figure 1. Effect of variety on dry matter content in peel at different days after storage of potato. Vertical bars represent SE values



D_1: Harvest at 80 DAP D_2: Harvest at 90 DAP

D_3: Harvest at 100 DAP D_4: Harvest at 110 DAP

Figure 2. Effect of days to harvest on dry matter content in peel at different days after storage of potato. Vertical bars represent SE values

Table 1. Combined effect of different variety and time of harvest of potato at different days after storage on dry matter content in peel

Treatment	Dry matter content in peel (%) at					
	Before storage	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
V_1D_1	12.25 h	14.16 j	15.05 fg	15.50 g	15.63 g	19.38 fg
V_1D_2	18.47 b-e	20.30 c-e	22.89 bc	23.67 bc	23.47 b-d	26.60 bc
V_1D_3	21.38 ab	21.51 b	25.00 ab	26.19 ab	25.89 ab	27.38 ab
V_1D_4	23.30 a	23.66 a	26.71 a	28.20 a	28.80 a	28.60 a
V_2D_1	16.06 d-g	17.83 f-h	14.61 fg	18.91 d-f	21.48 ce	22.82 fg
V_2D_2	16.42 d-g	18.92 fg	21.46 cd	23.05 bc	21.93 cd	24.15 cd
V_2D_3	17.20 c-f	19.20 ef	22.00 b-d	23.47 bc	22.59 b-d	24.60 b-d
V_2D_4	19.51 b-d	19.73 cd	22.42 bc	24.32 bc	25.70 b	25.71 bc
V_3D_1	13.39 gh	16.59 ij	16.96 ef	18.07 e-g	18.07 f	23.49 ef
V_3D_2	15.26 e-h	18.22 gh	18.63 de	17.56 fg	20.17 d-f	24.12 de
V_3D_3	20.33 a-c	21.07 bc	22.10 bc	22.36 c	25.39 b	26.27 bc
V_3D_4	17.63 c-f	19.27 d-f	21.96 b-d	23.63 bc	23.41 b-d	24.82 b-d
V_4D_1	14.20 f-h	15.36 hi	12.13 g	17.25 fg	18.39 ef	19.60 g
V_4D_2	15.27 e-h	18.59 gh	20.35 cd	21.00 c-e	20.57 c-f	23.82 cd
V_4D_3	16.49 d-g	19.41 fg	21.33 cd	21.89 cd	21.24 c-f	24.04 cd
V_4D_4	18.68 b-e	20.08 c-e	22.97 bc	23.86 bc	23.91 bc	25.38 bc
SE	1.093	0.601	1.302	1.052	1.038	1.022
Level of significance	0.01	0.01	0.05	0.01	0.01	0.05
CV(%)	10.99	5.50	11.05	8.36	8.08	7.25

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BARI TPS-1 D_1: Harvest at 80 DAP

V_2: BARI TPS-2 D_2: Harvest at 90 DAP

V_3: HPS-364/67 D_3: Harvest at 100 DAP

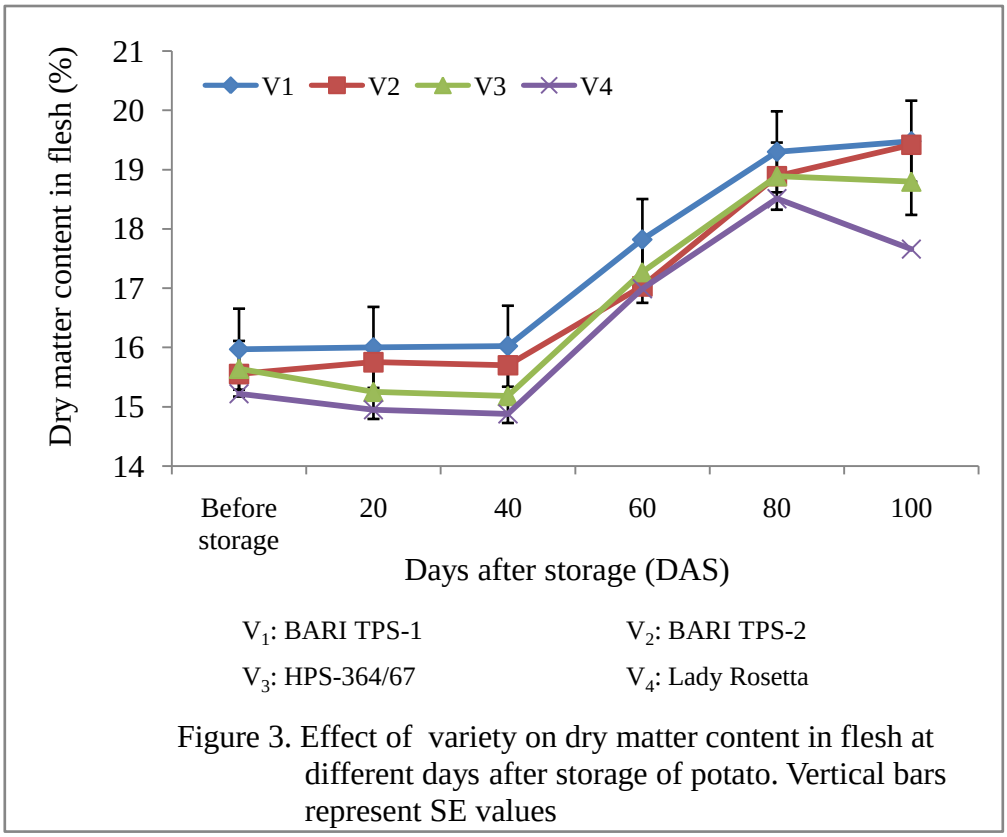
V_4: Lady Rosetta D_4: Harvest at 110 DAP

4.2 Dry matter of flesh

Dry matter content in flesh of potato showed statistically significant variation due to different variety (Appendix III). At before storage and 20, 40, 60, 80, 100 DAS, the highest dry matter in flesh (15.97, 16.00, 16.02, 17.82, 19.30 and 19.48%) was recorded from V_1 (BARI TPS-1), whereas the lowest (15.22, 14.95, 14.88, 16.99, 18.51 and 17.66%) was observed from V_4 (Lady Rosetta) for same data recorded days, respectively (Figure 3).

Statistically significant variation was recorded for dry matter content in flesh of potato for different time of harvest (Appendix III). At before storage and 20, 40, 60, 80 and 100 DAS, the highest dry matter in flesh (16.31, 16.90, 17.07, 18.41, 20.39 and 20.71%) was observed from D_4 (harvest at 110 DAP) which was statistically similar (16.06, 16.50, 16.20, 18.04, 19.91 and 20.04%) to D_3 (harvest at 100 DAP) and followed (15.90, 15.70, 15.10, 17.45, 19.23 and 19.04%) by D_2 (harvest at 90 DAP), while the lowest (14.12, 12.85, 13.42, 15.21, 16.08 and 15.6%) was recorded from D_1 (harvest at 80 DAP) at same data recorded days (Figure 4). Jeong *et al*. (1996) reported gradual increase in dry matter content in flesh until 100 days after planting, and showed a decrease thereafter.

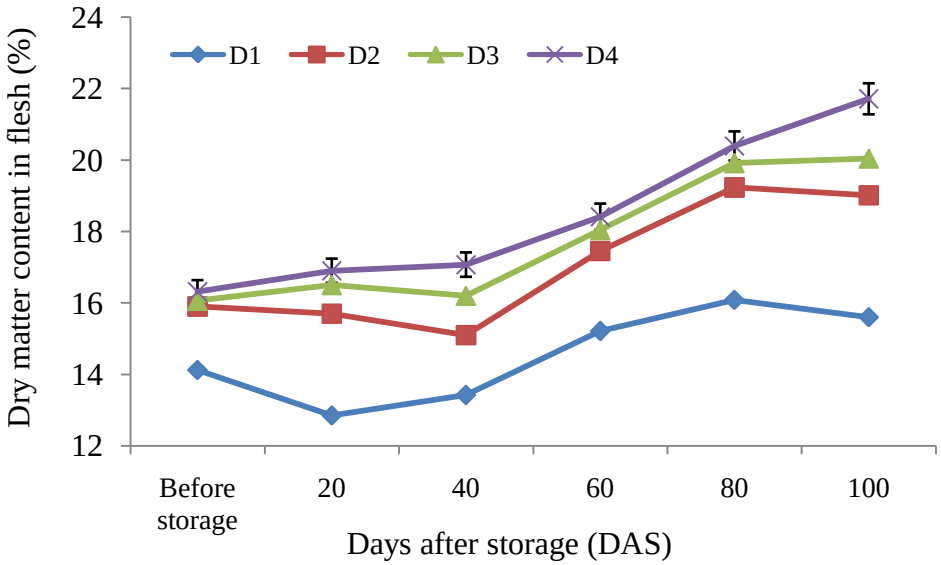
Statistically significant variation was recorded for dry matter content in flesh of different potato varieties due to the combined effect of different variety and time of harvest (Appendix III). At before storage and 20, 40, 60, 80 and 100 DAS, the highest dry matter in flesh (16.99, 17.75, 18.80, 19.93, 21.71 and 22.07%) was observed from V_1D_4 (BARI TPS-1 and harvest at 110 DAP) and the lowest dry matter in flesh (13.62, 12.16, 12.86, 13.73, 14.24 and 14.40%) was recorded from V_1D_1 (BARI TPS-1 and harvest at 80 DAP) at same data recorded days (Table 2).



V_1: BARI TPS-1 V_2: BARI TPS-2

V_3: HPS-364/67 V_4: Lady Rosetta

Figure 3. Effect of variety on dry matter content in flesh at different days after storage of potato. Vertical bars represent SE values



D_1: Harvest at 80 DAP D_2: Harvest at 90 DAP

D_3: Harvest at 100 DAP D_4: Harvest at 110 DAP

Figure 4. Effect of days to harvest on dry matter content in flesh at different days after storage of potato. Vertical bars represent SE values

Table 2. Combined effect different variety and time of harvest of potato at different days after storage on dry matter content in flesh of potato

Treatment	Dry matter content in flesh (%) at					
	Before storage	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
V_1D_1	13.62 f	12.16 g	12.86 g	13.73 i	14.24 g	14.40 h
V_1D_2	16.65 ab	16.55 abc	16.07 b-d	18.57 bc	20.21 bc	20.03 a-d
V_1D_3	16.64 ab	17.55 ab	17.33 ab	19.03 ab	21.04 ab	21.43 ab
V_1D_4	16.99 a	17.75 a	18.80 a	19.93 a	21.71 a	22.07 a
V_2D_1	14.29 ef	12.95 fg	14.87 d-f	16.03 h	16.31 f	15.57 gh
V_2D_2	15.64 cd	15.95 bcd	15.27 de	16.93 f-h	19.48 c	19.90 a-d
V_2D_3	15.97 bc	17.15 abc	15.47 c-e	17.23 e-g	19.68 c	21.10 a-c
V_2D_4	16.31 abc	16.95 abc	17.20 b	17.93 b-f	20.11 bc	21.10 a-c
V_3D_1	14.97 de	13.95 ef	13.40 f	16.50 gh	18.01 e	17.23 fg
V_3D_2	15.64 cd	14.55 de	14.33 ef	16.90 f-h	18.11 de	17.50 ef
V_3D_3	15.99 bc	15.75 cd	17.00 bc	18.33 b-e	19.68 c	19.57 b-e
V_3D_4	15.98 bc	16.76 abc	16.00 b-e	17.33 d-g	19.78 c	20.70 a-c
V_4D_1	13.62 f	12.35 g	13.53 f	14.57 i	15.74 f	15.20 h
V_4D_2	15.65 cd	15.76 cd	14.73 d-f	17.40 c-g	19.11 cd	18.40 d-f
V_4D_3	15.63 cd	15.55 cd	15.00 d-f	17.57 c-g	19.24 c	18.07 d-f
V_4D_4	15.98 bc	16.15 abcd	16.27 b-d	18.43 d	19.94 bc	18.97 c-f
SE	0.280	0.498	0.520	0.362	0.353	0.663
Level of significance	0.01	0.05	0.01	0.01	0.01	0.01
CV(%)	3.94	5.56	5.83	3.63	3.24	5.98

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BARI TPS-1 D_1: Harvest at 80 DAP

V_2: BARI TPS-2 D_2: Harvest at 90 DAP

V_3: HPS-364/67 D_3: Harvest at 100 DAP

V_4: Lady Rosetta D_4: Harvest at 110 DAP

4.3 Weight loss

Statistically significant variation was recorded for weight loss (Appendix IV). At 20, 40, 60, 80 and 100 DAS, the utmost weight loss (5.54, 6.90, 11.75, 16.51 and 18.00%) was recorded from V_4 (Lady Rosetta) which was followed (5.24, 6.51, 10.51, 15.42 and 16.71%) by V_3 (HPS-364/67), whereas the minimum weight loss (4.55, 6.15, 9.47, 13.04 and 13.78%) was observed from V_1 (BARI TPS-1) which was followed (5.05, 6.71, 10.55, 14.97 and 15.85%) by V_2 (BARI TPS-2) for same DAS, respectively (Table 3). Madalageri (1999) reported that the TPS progenies were as good as those of tuber planted crops in respect of physiological loss in weight after 3 months of storage under ambient conditions. Hossain *et al*. (1992) reported that the maximum tuber weight loss (31.15%) was recorded in the check variety Cardinal. Hossain and Rashid (1991) reported that 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.

Significant differences was observed for weight loss of potato for different time of harvest (Appendix IV). At 20, 40, 60, 80 and 100 DAS, the maximum weight loss (5.55, 7.00, 11.30, 16.34 and 17.87%) was observed from D_1 (harvest at 80 DAP) which was followed (5.14, 6.63, 10.71, 15.44 and 16.16%) by D_2 (harvest at 90 DAP), while the minimum weight loss (4.64, 6.20, 9.58, 13.24 and 14.99%) was recorded from D_4 (harvest at 110 DAP) which was followed (5.05, 6.44, 10.69, 14.91 and 15.32%) by D_3 (harvest at 100 DAP) at same DAS (Table 3).

Weight loss of potato showed statistically significant variation due to the combined effect of different variety and time of harvest (Appendix IV). At 20, 40, 60, 80 and 100 DAS, the maximum weight loss (6.07, 7.26, 12.63, 18.04 and 19.60%) was observed from V_4D_1 (Lady Rosetta and harvest at 80 DAP) and the minimum (3.53, 5.52, 8.21, 10.79 and 11.72%) was recorded from V_1D_4 (BARI TPS-1 and harvest at 110 DAP) at same DAS (Table 4).

Table 3. Effect of different variety and time of harvest of potato at different days after storage on weight loss of potato

Treatment	Weight loss (%) at				
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
Variety					
V_1	4.55 c	6.15 c	9.47 c	13.04 c	13.78 d
V_2	5.05 b	6.71 ab	10.55 b	14.97 b	15.85 c
V_3	5.24 b	6.51 b	10.51 b	15.42 b	16.71 b
V_4	5.54 a	6.90 a	11.75 a	16.51 a	18.00 a
SE	0.086	0.106	0.200	0.289	0.293
Level of significance	0.01	0.01	0.01	0.01	0.01
Time of harvest					
D_1	5.55 a	7.00 a	11.30 a	16.34 a	17.87 a
D_2	5.14 b	6.63 b	10.71 b	15.44 b	16.16 b
D_3	5.05 b	6.44 bc	10.69 b	14.91 b	15.32 c
D_4	4.64 c	6.20 c	9.58 c	13.24 c	14.99 d
SE	0.086	0.106	0.200	0.289	0.293
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	5.88	5.57	6.54	6.68	6.31

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BARI TPS-1
V_2: BARI TPS-2
V_3: HPS-364/67
V_4: Lady Rosetta

D_1: Harvest at 80 DAP
D_2: Harvest at 90 DAP
D_3: Harvest at 100 DAP
D_4: Harvest at 110 DAP

Table 4. Combined effect of different variety and time of harvest of potato at different days after storage on weight loss of potato

Treatment	Weight loss (%) at				
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
V_1D_1	5.53 a-c	6.74 a-d	10.37 c-e	14.29 cd	15.99 g
V_1D_2	4.16 e	6.20 d	9.61 de	13.34 d	13.78 k
V_1D_3	4.97 cd	6.14 de	9.69 de	13.72 d	13.63 k
V_1D_4	3.53 f	5.52 e	8.21 f	10.79 e	11.72 l
V_2D_1	4.97 cd	7.03 a-c	10.43 c-e	15.75 bc	17.41 d
V_2D_2	5.71 ab	7.17 ab	11.39 a-c	15.72 bc	15.27 h
V_2D_3	4.49 de	6.15 de	10.20 c-e	14.01 cd	14.21 j
V_2D_4	5.04 cd	6.50 b-d	10.20 c-e	14.39 cd	16.52 f
V_3D_1	5.62 ab	7.20 ab	12.03 ab	17.28 ab	18.49 b
V_3D_2	5.26 bc	6.46 cd	10.55 c-e	15.79 bc	17.06 e
V_3D_3	5.02 cd	6.23 d	10.23 c-e	14.68 cd	15.31 h
V_3D_4	4.61 de	6.14 de	9.22 ef	13.15 d	14.87 i
V_4D_1	6.07 a	7.26 a	12.63 a	18.04 a	19.60 a
V_4D_2	5.45 bc	6.69 a-d	11.28 bc	16.89 ab	18.52 b
V_4D_3	5.72 ab	7.01 a-c	12.37 ab	17.21 ab	18.12 c
V_4D_4	5.36 bc	6.64 a-d	10.69 cd	14.64 cd	16.85 e
SE	0.173	0.211	0.399	0.577	0.586
Level of significance	0.01	0.05	0.05	0.05	0.01
CV(%)	5.88	5.57	6.54	6.68	6.31

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BARI TPS-1 D_1: Harvest at 80 DAP

V_2: BARI TPS-2 D_2: Harvest at 90 DAP

V_3: HPS-364/67 D_3: Harvest at 100 DAP

V_4: Lady Rosetta D_4: Harvest at 110 DAP

4.4 Percentage of rotten tubers

Percentage of rotten tubers of potato showed statistically significant variation for different variety under the present study (Appendix V). Data revealed that at 20, 40, 60, 80 and 100 DAS, the highest percentage of rotten tubers (2.44, 3.41, 5.78, 6.84 and 8.79%) was recorded in V_4 (Lady Rosetta) which was statistically similar with V_3 (HPS-364/67) (2.36, 3.38, 5.61, 6.79, and 8.77%) and V_2 (BARI TPS-2) (2.32, 3.30, 5.50, 6.43 and 8.65%), whereas the lowest percentage (1.62, 2.47, 4.30, 5.25 and 7.10%) was observed from V_1 (BARI TPS-1) for same DAS, respectively (Table 5). Madalageri (1999) reported that the TPS progenies were as good as those of tuber planted crops in respect of rotten after 3 months of storage under ambient conditions.

Percent of rotten tuber was significantly influenced by different time of harvest (Appendix V). At 20, 40, 60, 80 and 100 DAS, the highest percentage of rotten tubers (2.69, 3.69, 6.46, 7.69 and 9.49%, respectively) was observed from D_1 (harvest at 80 DAP) which was followed (2.29, 3.29, 5.45, 6.47 and 8.59%) by D_2 (harvest at 90 DAP), while the lowest (1.72, 2.54, 4.18, 5.10 and 7.18%) was recorded from D_4 (harvest at 110 DAP) which was followed (2.04, 3.04, 5.10, 6.04 and 8.04%) by D_3 (harvest at 100 DAP) at same DAS (Table 5).

Combined effect of different variety and time of harvest also showed statistically significant variation for percentage of rotten tubers of potato at different days after storage (Appendix V). It was found that at 20, 40, 60, 80 and 100 DAS, the highest percentage of rotten tubers (3.13, 4.13, 7.21, 8.41 and 9.91%) was observed from V_4D_1 (Lady Rosetta and harvest at 80 DAP) and the lowest percentage of rotten tubers (1.33, 1.81, 3.23, 4.25 and 6.13%) was recorded from V_1D_4 (BARI TPS-1 and harvest at 110 DAP) at same DAS (Table 6).

Table 5. Effect of different variety and time of harvest of potato at different days after storage on percentage of rotten tubers

Treatment	Percentage of rotten tubers at				
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
Variety					
V_1	1.62 b	2.47 b	4.30 b	5.25 b	7.10 b
V_2	2.32 a	3.30 a	5.50 a	6.43 a	8.65 a
V_3	2.36 a	3.38 a	5.61 a	6.79 a	8.77 a
V_4	2.44 a	3.41 a	5.78 a	6.84 a	8.79 a
SE	0.056	0.071	0.126	0.138	0.137
Level of significance	0.01	0.01	0.01	0.01	0.01
Time of harvest					
D_1	2.69 a	3.69 a	6.46 a	7.69 a	9.49 a
D_2	2.29 b	3.29 b	5.45 b	6.47 b	8.59 b
D_3	2.04 c	3.04 c	5.10 b	6.04 c	8.04 c
D_4	1.72 d	2.54 d	4.18 c	5.10 d	7.18 d
SE	0.056	0.071	0.126	0.138	0.137
Level of significance	0.01	0.01	0.01	0.01	0.01
CV(%)	8.80	7.84	8.26	7.57	5.41

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BARI TPS-1
V_2: BARI TPS-2
V_3: HPS-364/67
V_4: Lady Rosetta

D_1: Harvest at 80 DAP
D_2: Harvest at 90 DAP
D_3: Harvest at 100 DAP
D_4: Harvest at 110 DAP

Table 6. Combined effect of different variety and time of harvest of potato at different days after storage on percentage of rotten tubers

Treatment	Percentage of rotten tubers at				
	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
V_1D_1	1.95 f-h	2.99 fg	5.39 c-e	6.57 c-e	8.52 cd
V_1D_2	1.66 h-j	2.62 gh	4.40 fg	5.18 fg	6.96 fg
V_1D_3	1.54 ij	2.46 h	4.20 fg	5.00 f-h	6.80 fg
V_1D_4	1.33 j	1.81 i	3.23 h	4.25 h	6.13 g
V_2D_1	2.80 ab	3.82 ab	6.56 ab	7.83 ab	9.68 ab
V_2D_2	2.57 b-d	3.61 b-d	5.62 cd	6.57 c-e	9.35 a-c
V_2D_3	2.06 e-g	3.04 e-g	4.93 d-f	5.61 f	8.02 de
V_2D_4	1.85 g-i	2.72 gh	4.89 d-f	5.71 ef	7.54 ef
V_3D_1	2.88 ab	3.81 ab	6.68 ab	7.96 ab	9.86 a
V_3D_2	2.67 bc	3.70 a-c	6.20 bc	7.34 bc	9.50 ab
V_3D_3	2.38 c-e	3.46 b-e	5.78 c	6.83 c	8.87 b-d
V_3D_4	1.56 ij	2.37 h	3.94 gh	4.57 gh	6.78 fg
V_4D_1	3.13 a	4.13 a	7.21 a	8.41 a	9.91 a
V_4D_2	2.25 d-f	3.24 d-f	5.60 cd	6.79 c	8.55 cd
V_4D_3	2.18 e-g	3.18 d-f	5.49 cd	6.71 cd	8.46 d
V_4D_4	2.14 e-g	3.27 c-f	4.66 efg	5.88 d-f	8.27 de
SE	0.111	0.142	0.253	0.276	0.274
Level of significance	0.01	0.01	0.05	0.01	0.01
CV(%)	8.80	7.84	8.26	7.57	5.41

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BARI TPS-1 D_1: Harvest at 80 DAP

V_2: BARI TPS-2 D_2: Harvest at 90 DAP

V_3: HPS-364/67 D_3: Harvest at 100 DAP

V_4: Lady Rosetta D_4: Harvest at 110 DAP

4.5 Days to start of sprouting

Days to start of sprouting of potato showed statistically significant variation for days required due to different variety under the present trial (Appendix VI). The maximum days to start of sprouting (48.25) was recorded from V_1 (BARI TPS-1) which was statistically similar (47.25 days and 46.00 days) with V_2 (BARI TPS-2) and V_4 (Lady Rosetta), whereas the minimum days to start of sprouting (43.00) was observed from V_3 (HPS-364/67) (Table 7). Madalageri (1999) reported that the TPS progenies were as good as those of tuber planted crops in respect of sprouted tubers after 3 months of storage under ambient conditions. Rasul *et al*., 1997 reported that cent percent sprouting was earlier in recommended varieties/lines (96 days) than of exotic ones (118.7 days).

Significant difference was recorded for days to start of sprouting potato for different time of harvest in this study (Appendix VI). The maximum days to start of sprouting (48.83) was observed from D_4 (harvest at 110 DAP) which was statistically similar (47.17) with D_3 (harvest at 100 DAP), while the minimum (44.00) was recorded from D_1 (harvest at 80 DAP) which was statistically similar (44.50) with D_2 (harvest at 90 DAP) (Table 7).

Days to start of sprouting of potato also showed statistically significant variation due to the combined effect of different variety and time of harvest (Appendix VI). The maximum days to start of sprouting (51.67) was observed from V_1D_3 (BARI TPS-1 and harvest at 100 DAP) and V_1D_4 (BARI TPS-1 and harvest at 110 DAP), while the minimum (39.33) was recorded in V_4D_1 (Lady Rosetta and harvest at 80 DAP) (Table 8).

4.6 Apical sprout length

Statistically significant variation was recorded for apical sprout length of potato for different variety under the present trial (Appendix VI). The longest apical sprout length (1.75 cm) was recorded from V_1 (BARI TPS-1) which was statistically similar (1.70 cm) with V_2 (BARI TPS-2) and closely followed (1.68 cm) by V_3 (HPS-364/67), whereas the smallest apical sprout length (1.64 cm)

from V_4 (Lady Rosetta) (Table 7). Roy *et al*. (2006) also reported similar opinion on apical sprout length of TPS variety.

Apical sprout length of sprouting potato showed statistically significant variation for different time of harvest (Appendix VI). The longest apical sprout length (1.84 cm) was observed from D_4 (harvest at 110 DAP) which was closely followed (1.78 cm) by D_3 (harvest at 100 DAP), while the smallest (1.47 cm) from D_1 (harvest at 80 DAP) which was closely followed (1.68 cm) by D_2 (harvest at 90 DAP) (Table 7).

The combined effect of different variety and time of harvest was also significant for apical sprout length (Appendix VI). Data revealed that the longest apical sprout length (2.01 cm) was observed from V_1D_4 (BARI TPS-1 and harvest at 110 DAP), while the smallest (1.31 cm) was recorded from V_4D_1 (Lady Rosetta and harvest at 80 DAP) (Table 8). Thus the similar sprout growth also recorded under ambient storage condition by Roy *et al*., 2006.

4.7 Days to start of rottening

Different variety showed statistically significant variation was for days to start of rottening of potato (Appendix VI). The highest days to start of rottening (17.83) was recorded from V_1 (BARI TPS-1) which was statistically similar (17.25 days) to V_2 (BARI TPS-2), while the lowest days to start of rottening (16.58) was observed from V_4 (Lady Rosetta) which was statistically similar (16.92) to V_3 (HPS-364/67) (Table 7).

Significant statistical variation was recorded for days to start of rottening of potato for different time of harvest (Appendix VI). The highest days to start of rottening (18.33) was observed from D_4 (harvest at 110 DAP) which was statistically similar (17.83) with D_3 (harvest at 100 DAP), while the lowest days to start of rottening (15.17) was recorded from D_1 (harvest at 80 DAP) which was followed (17.25 days) by D_2 (harvest at 90 DAP) (Table 7).

Statistically significant variation was recorded for days to start of rottening of potato due to the combined effect of different variety and time of harvest (Appendix VI). The highest days to start of rottening (20.00) was observed from V_1D_4 (BARI TPS-1 and harvest at 110 DAP), while the lowest (14.00) was found in V_4D_1 (Lady Rosetta and harvest at 80 DAP) (Table 8).

4.8 Days to start of shriveling

Statistically significant variation was recorded for days to start of shriveling of potato for different variety under the present trial (Appendix VI). The maximum days to start of shriveling (82.58) was recorded from V_1 (BARI TPS-1) which was statistically similar (80.17 days) to V_2 (BARI TPS-2), while the minimum (76.58) was observed from V_4 (Lady Rosetta) which was statistically similar (78.08) by V_3 (HPS-364/67) (Table 7). 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).

Days to start of shriveling of potato showed statistically significant variation for different time of harvest (Appendix VI). The maximum days to start of shriveling (87.08) was observed from D_4 (harvest at 110 DAP) which was statistically similar (83.83 days) to D_3 (harvest at 100 DAP), while the minimum (68.58) was recorded from D_1 (harvest at 80 DAP) which was followed (77.92 days) by D_2 (harvest at 90 DAP) (Table 7).

Combined effect of different variety and time of harvest varied significantly for days to start of shriveling of potato due to the (Appendix VI). The maximum days to start of shriveling (95.67) was observed from V_1D_4 (BARI TPS-1 and harvest at 110 DAP), while the minimum (61.33) was recorded in V_4D_1 (Lady Rosetta and harvest at 80 DAP) (Table 8).

Table 7. Effect of different variety and time of harvest on days to start of sprouting, apical sprout length, days to start rottening and days to start of shriveling of potato

Treatment	Days to start of sprouting	Apical sprout length (cm)	Days to start rottening	Days to start of shriveling
Variety				
V_1	48.25 a	1.75 a	17.83 a	82.58 a
V_2	47.25 a	1.70 ab	17.25 ab	80.17 ab
V_3	43.00 b	1.68 bc	16.92 bc	78.08 bc
V_4	46.00 a	1.64 c	16.58 c	76.58 c
SE	0.861	0.548	0.213	1.998
Level of significance	0.01	0.01	0.01	0.01
Time of harvest				
D_1	44.00 b	1.47 d	15.17 c	68.58 d
D_2	44.50 b	1.68 c	17.25 b	77.92 c
D_3	47.17 a	1.78 b	17.83 ab	83.83 b
D_4	48.83 a	1.84 a	18.33 a	87.08 a
SE	0.861	0.548	0.213	1.998
Level of significance	0.01	0.01	0.01	0.01
CV(%)	6.47	3.89	4.29	4.47

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BARI TPS-1
V_2: BARI TPS-2
V_3: HPS-364/67
V_4: Lady Rosetta

D_1: Harvest at 80 DAP
D_2: Harvest at 90 DAP
D_3: Harvest at 100 DAP
D_4: Harvest at 110 DAP

Table 8. Combined effect of different variety and time of harvest on days to start of sprouting, apical sprout length, days to start rottening and days to start of shriveling of potato

Treatment	Days to start of sprouting	Apical sprout length (cm)	Days to start rottening	Days to start of shriveling
V_1D_1	45.67 b-e	1.44 g	14.00 f	69.00 h
V_1D_2	45.67 b-e	1.79 b-d	18.33 bc	83.33 cd
V_1D_3	51.67 a	1.89 b	19.00 ab	90.00 ab
V_1D_4	51.67 a	2.01 a	20.00 a	95.67 a
V_2D_1	43.33 d-f	1.61 ef	16.00 e	74.67 f-h
V_2D_2	46.33 a-e	1.67 de	17.33 c-e	78.67 d-f
V_2D_3	48.33 a-d	1.71 c-e	17.67 cd	80.33 d-f
V_2D_4	51.00 ab	1.81 bc	18.00 bc	87.00 bc
V_3D_1	45.00 c-e	1.51 fg	16.00 e	69.33 gh
V_3D_2	45.00 c-e	1.61 ef	16.33 de	74.00 f-h
V_3D_3	42.00 ef	1.85 b	17.67 cd	87.00 bc
V_3D_4	42.67 d-f	1.73 c-e	17.67 cd	82.00 c-e
V_4D_1	39.33 f	1.31 h	14.67 f	61.33 i
V_4D_2	41.00 ef	1.64 e	17.00 c-e	75.67 e-g
V_4D_3	49.33 a-c	1.69 de	17.00 c-e	78.00 d-f
V_4D_4	50.00 a-c	1.79 b-d	17.67 cd	83.67 b-d
SE	1.722	1.096	0.425	3.996
Level of significance	0.01	0.01	0.01	0.01
CV(%)	6.47	3.89	4.29	4.47

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BARI TPS-1 D_1: Harvest at 80 DAP

V_2: BARI TPS-2 D_2: Harvest at 90 DAP

V_3: HPS-364/67 D_3: Harvest at 100 DAP

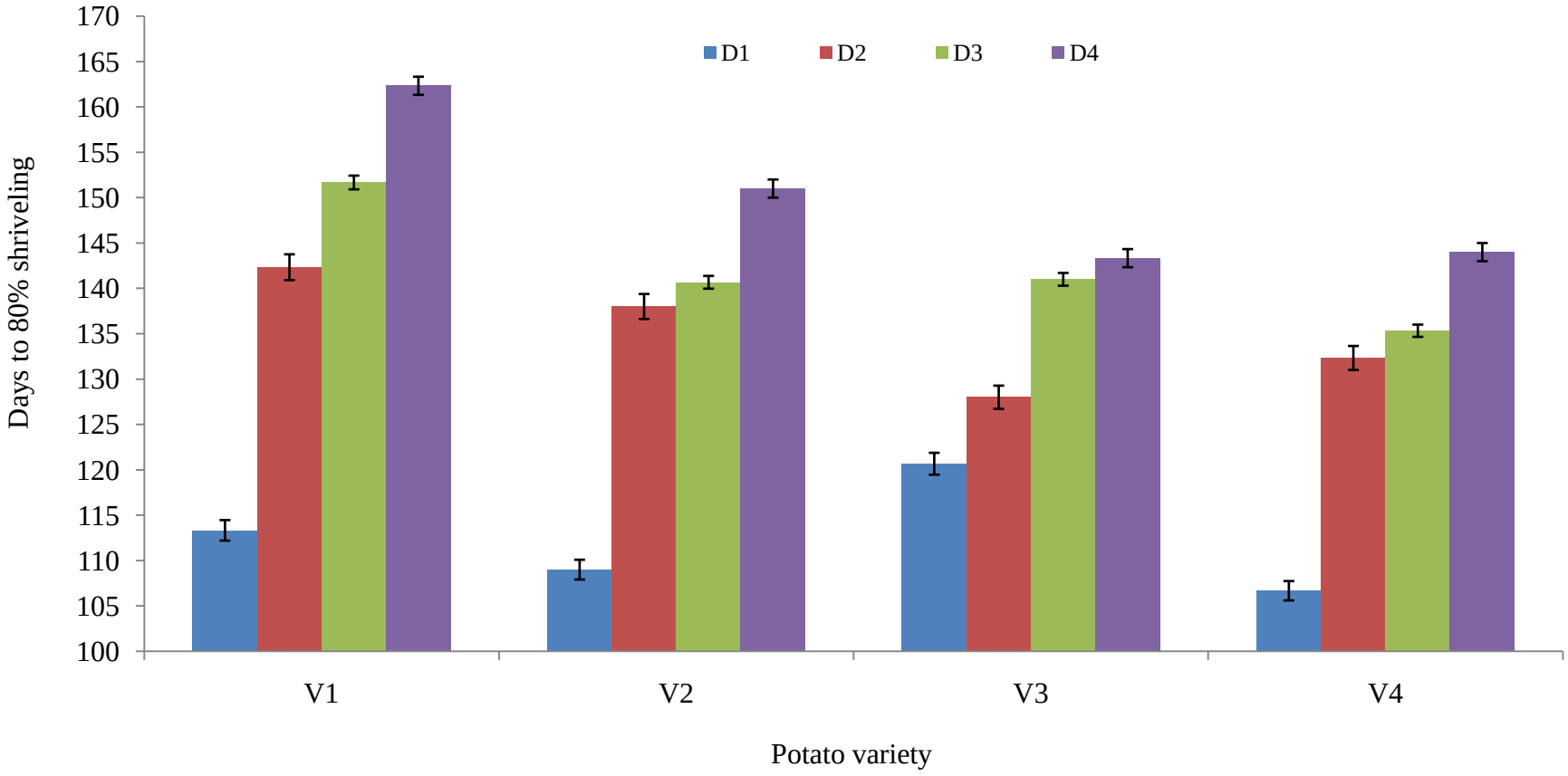
V_4: Lady Rosetta D_4: Harvest at 110 DAP

4.9 Days to 80% shriveling

Significant variation was recorded for days to 80% shriveling of potato for different variety under the present trial (Appendix VI). The maximum days to 80% shriveling (140.75) was recorded from V_1 (BARI TPS-1), while the minimum days (131.25) was observed from V_4 (Lady Rosetta) which was statistically similar (133.25 day and 134.67 days) with V_3 (HPS-364/67) and V_2 (BARI TPS-2) (Figure 5).

Different time of harvest showed statistically significant variation for days to 80% shriveling of potato (Appendix VI). The maximum days to 80% shriveling (150.17) was observed from D_4 (harvest at 110 DAP) which was followed (142.17 days) by D_3 (harvest at 100 DAP), while the minimum days (112.42 days) was recorded in D_1 (harvest at 80 DAP) which was followed (135.17 days) by D_2 (harvest at 90 DAP) (Figure 6). Early harvested tubers shriveled quickly due to immaturity and less accumulation of starch compared to late harvested tubers.

Days to 80% shriveling of potato showed also significant variation due to the combined effect of different variety and time of harvest (Appendix VI). The maximum days to 80% shriveling (162.33) was observed from V_1D_4 (BARI TPS-1 and harvest at 110 DAP), while the minimum (106.67) was recorded from V_4D_1 (Lady Rosetta and harvest at 80 DAP) (Figure 7). Hossain *et al*. (1994) reported same results for non-TPS British potato cultivars.



V_1: BARI TPS-1 V_2: BARI TPS-2 D_1: Harvest at 80 DAP D_2: Harvest at 90 DAP

V_3: HPS-364/67 V_4: Lady Rosetta D_3: Harvest at 100 DAP D_4: Harvest at 110 DAP

Figure 7. Combined effect of variety and time of harvest on days to 80% shriveling of potato. Vertical bars represent SE values

4.10 Specific gravity

Specific gravity of potato showed statistically significant variation for different variety (Appendix VII). At harvest and 100 DAS, the highest specific gravity (1.12 and 1.14) was recorded from V_3 (HPS-364/67) which was statistically similar (1.11 and 1.13) with V_4 (Lady Rosetta), whereas the lowest (1.09 and 1.12) was observed from V_1 (BARI TPS-1) which was statistically similar (1.10 and 1.13) to V_2 (BARI TPS-2), respectively (Table 9).

Statistically significant variation was recorded for specific gravity of potato for different time of harvest (Appendix VII). At harvest and 100 DAS, the highest specific gravity (1.12 and 1.14) was observed from D_1 (harvest at 80 DAP) and D_2 (harvest at 90 DAP) which was followed (1.10 and 1.13) by D_3 (harvest at 100 DAP), while the lowest (1.08 and 1.11) was recorded from D_4 (harvest at 110 DAP), respectively (Table 9). Jeong *et al*. (1996) reported gradual increase in specific gravity until 100 days after planting, and showed a decrease thereafter.

Combined effect of different variety and time of harvest also varied significantly for specific gravity (Appendix VII). Data revealed that at harvest and 100 DAS, the highest specific gravity (1.13 and 1.16) was observed from V_3D_1 (HPS 364/67 and harvest at 80 DAP), while the lowest specific gravity (1.06 and 1.09) was recorded from V_1D_4 (BARI TPS-1 and harvest at 110 DAP), respectively for same data recording days (Table 10).

4.11 Reducing sugar

Different variety showed statistically significant variation for reducing sugar of potato under the present trial (Appendix VII). At harvest and 100 DAS, the highest reducing sugar (0.29% and 0.55%) was recorded from V_4 (Lady Rosetta) which was closely followed (0.28% and 0.53%) by V_1 (BARI TPS-1), whereas the lowest reducing sugar (0.24% and 0.49%) was observed from V_3 (HPS-364/67), respectively for same data recording days (Table 9).

Reducing sugar of potato showed statistically significant variation for different time of harvest (Appendix VII). At harvest and 100 DAS, the highest reducing sugar (0.29% and 0.59%) was observed from D_4 (harvest at 110 DAP) which was followed (0.28 and 0.58) by D_3 (harvest at 100 DAP), while the lowest reducing sugar (0.25% and 0.45%) was recorded from D_1 (harvest at 80 DAP), which was followed (0.27% and 0.47%) by D_2 (harvest at 90 DAP), respectively for same data recording days (Table 9). Similar trend of increasing reducing sugars in tubers has been reported by Kibria (1983) and Boyed and Duncan (1981).

The combined effect of different variety and time of harvest was also significant for reducing sugar (Appendix VII). At harvest and 100 DAS, the highest reducing sugar (0.32% and 0.62%) was observed from V_4D_4 (Lady Rosetta and harvest at 110 DAP), while the lowest reducing sugar (0.23% and 0.43%) was recorded from V_3D_1 (HPS-364/67 and harvest at 80 DAP), respectively for same data recording days (Table 10).

4.12 Non reducing sugar

Significant variation was recorded for non reducing sugar of potato for different variety under the present trial (Appendix VII). Data revealed that at harvest and 100 DAS, the utmost non reducing sugar (0.28% and 0.21%) was recorded from V_4 (Lady Rosetta), whereas the lowest (0.25% and 0.19%) was observed from V_3 (HPS-364/67), respectively for same data recording days (Table 9).

Different time of harvest showed statistically significant variation for non reducing sugar (Appendix VII). At harvest, the maximum non reducing sugar (0.30%) was observed from D_4 (harvest at 110 DAP), while the minimum (0.21%) was recorded from D_1 (harvest at 80 DAP). At 100 DAS, the highest non reducing sugar (0.23%) was observed from D_2 (harvest at 90 DAP), while the lowest (0.18%) was recorded from D_4 (harvest at 110 DAP) (Table 9).

Combined effect of different variety and time of harvest showed statistically significant variation for non reducing sugar of potato (Appendix VII). At harvest, the highest non reducing sugar (0.32%) was observed from V_3D_4 (HPS-364/67 and harvest at 110 DAP), while the lowest non reducing sugar (0.19%) was recorded from V_1D_1 (BARI TPS-1 and harvest at 80 DAP). At 100 DAS, the highest non reducing sugar (0.24%) was observed from V_1D_1 (BARI TPS-1 and harvest at 80 DAP), while the lowest non reducing sugar (0.17%) was recorded in V_1D_3 (BARI TPS-1 and harvest at 100 DAP) (Table 10).

4.13 Total sugar

Total sugar of potato varied significantly for different variety (Appendix VII). At harvest and 100 DAS, the highest total sugar (0.55% and 0.75%) was recorded from V_4 (Lady Rosetta), whereas the lowest (0.51% and 0.69%) was observed from V_3 (HPS-364/67), respectively for same data recording days (Table 9).

Statistically significant variation was recorded for total sugar of potato for different time of harvest (Appendix VII). At harvest and 100 DAS, the highest total sugar (0.59% and 0.78%) was observed from D_4 (harvest at 110 DAP) which was followed (0.56% and 0.76%) by D_3 (harvest at 100 DAP), while the lowest (0.46% and 0.67%) was recorded from D_1 (harvest at 80 DAP), which was followed (0.52% and 0.69%) by D_2 (harvest at 90 DAP), respectively (Table 9).

Combined effect of different variety and time of harvest showed significant variation for total sugar of potato (Appendix VII). At harvest and 100 DAS, the highest total sugar (0.61% and 0.82%) was observed from V_4D_4 (Lady Rosetta and harvest at 110 DAP), while the lowest (0.44% and 0.63%) was recorded from V_3D_1 (HPS-364/67 and harvest at 80 DAP), respectively (Table 10).

4.14 Starch content

Different variety showed significant differences for starch content of potato (Appendix VII). At harvest and 100 DAS, the highest starch content (18.89% and 20.51%) was recorded from V_3 (HPS-364/67), whereas the lowest (17.32% and 19.11%) from V_2 (BARI TPS-2), respectively (Table 9). Rainys and Rudokas (2005) recorded the highest starch were recorded for Lady Rosetta (17.0-17.9%).

The combined effect of different variety and time of harvest was also significant for starch content (Appendix VII). At harvest and 100 DAS, the highest starch content (18.22% and 20.03%) was observed from D_1 (harvest at 80 DAP) which was followed (17.92% and 19.74%) by D_2 (harvest at 90 DAP), while the lowest (17.25% and 18.86%) was recorded from D_4 (harvest at 110 DAP), which was followed (17.51% and 19.26%) by D_3 (harvest at 100 DAP), respectively for same data recording days (Table 9). Jeong *et al*. (1996) reported gradual increase starch content until 100 days after planting, and showed a decrease thereafter.

Starch content of potato showed statistically significant variation due to the combined effect of different variety and time of harvest (Appendix VII). At harvest and 100 DAS, the highest starch content (19.50% and 21.12%) was observed from V_3D_1 (HPS-364/67 and harvest at 80 DAP), while the lowest starch content (16.97% and 18.50%) was recorded from V_2D_4 (BARI TPS-2 and harvest at 100 DAP), respectively for same data recording days (Table 10).

Table 9. Effect of different variety and time of harvest of potato at different days after storage on specific gravity, reducing sugar, non reducing sugar, total sugar and starch content in potato

Treatment	Specific gravity at		Reducing sugar at		Non reducing sugar at		Total sugar at		Starch content at	
	Harvest	100 DAS	Harvest	100 DAS	Harvest	100 DAS	Harvest	100 DAS	Harvest	100 DAS
Variety										
V_1	1.09 c	1.12 c	0.28 b	0.53 b	0.26 b	0.20 ab	0.52 c	0.73 b	17.33 b	19.12 b
V_2	1.10 b	1.13 b	0.27 b	0.52 b	0.27 a	0.20 ab	0.54 b	0.73 b	17.32 b	19.11 b
V_3	1.12 a	1.14 a	0.24 c	0.49 c	0.25 c	0.19 b	0.51 d	0.69c	18.89 a	20.51 a
V_4	1.11 a	1.13 ab	0.29 a	0.55 a	0.28 a	0.21 a	0.55 a	0.75 a	17.35 b	19.14 b
SE	0.015	0.024	0.012	0.005	0.016	0.018	0.014	0.016	0.315	0.415
Level of significance	0.01	0.01	0.01	0.01	0.01	0.05	0.01	0.01	0.01	0.01
Time of harvest										
D_1	1.12 a	1.14 a	0.25 d	0.45 d	0.21 d	0.23 a	0.46 d	0.67 d	18.22 a	20.03 a
D_2	1.12 a	1.14 a	0.27 c	0.47 c	0.25 c	0.22 a	0.52 c	0.69 c	17.92 b	19.74 b
D_3	1.10 b	1.13 b	0.28 b	0.58 b	0.28 b	0.19 b	0.56 b	0.76 b	17.51 c	19.26 c
D_4	1.08 c	1.11 c	0.29 a	0.59 a	0.30 a	0.18 b	0.59 a	0.78 a	17.25 d	18.86 d
SE	0.015	0.024	0.012	0.005	0.016	0.018	0.014	0.016	0.315	0.415
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	4.91	3.89	6.14	3.38	2.13	4.54	4.86	2.26	3.14	4.62

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BARI TPS-1

V_2: BARI TPS-2

V_3: HPS-364/67

V_4: Lady Rosetta

D_1: Harvest at 80 DAP

D_2: Harvest at 90 DAP

D_3: Harvest at 100 DAP

D_4: Harvest at 110 DAP

Table 10. Combined effect of different variety and time of harvest of potato at different days after storage on specific gravity, reducing, non reducing, total sugar and starch content in potato

Treatment	Specific gravity at		Reducing sugar at		Non reducing sugar at		Total sugar at		Starch content at	
	Harvest	100 DAS	Harvest	100 DAS	Harvest	100 DAS	Harvest	100 DAS	Harvest	100 DAS
V_1D_1	1.10 bc	1.13 bc	0.26 f-h	0.46 gh	0.19 f	0.24 a	0.45 g	0.69 g	17.79 e	19.74 b
V_1D_2	1.10 bc	1.13 bc	0.28 c-e	0.48 ef	0.23 d	0.23 a	0.51 e	0.71 f	17.52 f	19.47 bc
V_1D_3	1.09 c	1.11 de	0.29 b-d	0.59 bc	0.26 c	0.17 c	0.55 c	0.76 cd	17.02 gh	18.77 de
V_1D_4	1.06 d	1.09 f	0.29 bc	0.59 bc	0.29 b	0.18 c	0.58 b	0.77 c	17.00 gh	18.92 c-e
V_2D_1	1.12 a	1.14 ab	0.25 g-i	0.45 h	0.22 de	0.23 a	0.47 f	0.68 gh	17.78 e	19.53 b
V_2D_2	1.12 a	1.14 ab	0.27 d-f	0.47 fg	0.26 c	0.22 a	0.53 d	0.69 g	17.53 f	19.28 b-d
V_2D_3	1.09 c	1.12 cd	0.28 c-e	0.58 c	0.29 b	0.18 bc	0.57 b	0.76 cd	17.00 gh	18.75 de
V_2D_4	1.07 d	1.10 ef	0.29 b-d	0.59 bc	0.31 a	0.18 bc	0.60 a	0.77 c	16.97 h	18.50 e
V_3D_1	1.13 a	1.16 a	0.23 j	0.43 i	0.21 e	0.20 b	0.44 g	0.63 i	19.50 a	21.12 a
V_3D_2	1.12 a	1.15 a	0.24 ij	0.44 hi	0.26 c	0.20 b	0.50 e	0.64 i	19.10 b	20.72 a
V_3D_3	1.11 ab	1.14 ab	0.25 hi	0.55 d	0.29 b	0.19 bc	0.54 cd	0.74 e	18.97 c	20.72 a
V_3D_4	1.09 c	1.12 cd	0.25 hi	0.55 d	0.32 a	0.20 b	0.57 b	0.75 de	18.00 d	19.50 bc
V_4D_1	1.12 a	1.14 ab	0.27 e-g	0.47 fg	0.21e	0.20 b	0.48 f	0.67 h	17.80 e	19.75 b
V_4D_2	1.12 a	1.14 ab	0.29 b-d	0.49 e	0.25 c	0.23 a	0.54 cd	0.72 f	17.54 f	19.49 bc
V_4D_3	1.11 ab	1.13 bc	0.30 b	0.60 b	0.28 b	0.20 b	0.58 b	0.80 b	17.03 g	18.78 de
V_4D_4	1.10 bc	1.12 cd	0.32 a	0.62 a	0.29 b	0.20 b	0.61 a	0.82 a	17.02 gh	18.52 e
SE	0.030	0.047	0.024	0.010	0.031	0.035	0.028	0.031	0.630	0.890
Level of significance	0.05	0.05	0.01	0.01	0.01	0.01	0.05	0.01	0.01	0.05
CV(%)	4.91	3.89	6.14	3.38	2.13	4.54	4.86	2.26	3.14	4.62

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BARI TPS-1 D_1: Harvest at 80 DAP

V_2: BARI TPS-2 D_2: Harvest at 90 DAP

V_3: HPS-364/67 D_3: Harvest at 100 DAP

V_4: Lady Rosetta D_4: Harvest at 110 DAP

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at Laboratory of Department of Agronomy, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from March to August 2012 to study the influence of variety and date of harvesting on post harvest physiology of potato derived from TPS at ambient storage condition. The experiment consisted of 2 factors: Factor A: Potato variety (4 varieties) as- V_1: BARI TPS-1, V_2: BARI TPS-2, V_3: HPS-364/67 and V_4: Lady Rosetta; Factor B: Time of harvest (4 times) as- D_1: 80 DAP, D_2: 90 DAP, D_3: 100 DAP and D_4: 110 DAP. The experiment was laid out in a 2 factor Completely Randomized Design (CRD) with 3 replications.

For different varieties, the highest dry matter in peel (18.85, 19.66, 22.41, 23.39, 23.32 and 25.49%) was recorded from V_1, whereas the lowest (16.16, 18.36, 19.20, 21.00, 21.03 and 23.21%) was observed from V_4, at before storage and 20, 40, 60, 80, 100 DAS, respectively. The highest dry matter in flesh (15.97, 16.00, 16.02, 17.82, 19.30 and 19.48%) was recorded from V_1, whereas the lowest (15.22, 14.95, 14.88, 16.99, 18.51 and 17.66%) was observed from V_4 for same data recorded days, respectively. At 20, 40, 60, 80 and 100 DAS, the maximum weight loss (5.54, 6.90, 11.75, 16.51 and 18.00%) was recorded from V_4, whereas the minimum (4.55, 6.15, 9.47, 13.04 and 13.78%) was observed from V_1 for same DAS, respectively. At 20, 40, 60, 80 and 100 DAS, the maximum percentage of rotten tubers (2.44, 3.41, 5.78, 6.84 and 8.79%) was recorded from V_4, whereas the minimum percentage (1.62, 2.47, 4.30, 5.25 and 7.10%) was observed from V_1 for same DAS, respectively. The maximum days to start of sprouting (48.25) was recorded from V_1, whereas the minimum days (43.00) from V_3. The longest apical sprout length (1.75 cm) was recorded from V_1, whereas the shortest apical sprout length (1.64 cm) was observed from V_4. The maximum days to start of rottening (17.83) was recorded from V_1, while the minimum days

(16.58) from V_4. The maximum days to start of shriveling (82.58) was recorded from V_1, while the minimum days (76.58) from V_4. The maximum days to 80% shriveling (140.75) was recorded from V_1, while the minimum days (131.25) was observed from V_4.

At harvest and 100 DAS, the highest specific gravity (1.12 and 1.14) was recorded from V_3, whereas the lowest specific gravity (1.09 and 1.12) from V_1. At harvest and 100 DAS, the highest reducing sugar (0.29% and 0.55%) was recorded from V_4, whereas the lowest reducing sugar (0.24% and 0.49%) from V_3, respectively for same data recording days. At harvest and 100 DAS, the highest non reducing sugar (0.28% and 0.21%) was recorded from V_4, whereas the lowest non reducing sugar (0.25% and 0.19%) from V_3, respectively for same data recording days. At harvest and 100 DAS, the highest total sugar (0.55% and 0.75%) was recorded from V_4, whereas the lowest total sugar (0.51% and 0.69%) from V_3, respectively for same data recording days. At harvest and 100 DAS, the highest starch content (18.89% and 20.51%) was recorded from V_3, whereas the lowest starch content (17.32% and 19.11%) from V_2, respectively for same data recording days.

In case of time of harvest, at before storage and 20, 40, 60, 80, 100 DAS, the highest dry matter in peel (19.78, 20.43, 23.52, 25.00, 25.45 and 26.13%) was observed from D_4, while the lowest dry matter in peel (13.97, 15.99, 16.09, 17.43, 18.27 and 21.32%) was recorded in D_1. At before storage and 20, 40, 60, 80, 100 DAS, the highest dry matter in flesh (16.31, 16.90, 17.07, 18.41, 20.39 and 20.71%) was observed from D_4, while the lowest (14.12, 12.85, 13.42, 15.21, 16.08 and 16.10%) was recorded from D_1 at same data recorded days. At 20, 40, 60, 80 and 100 DAS, the maximum weight loss (5.55, 7.00, 11.30, 16.34 and 17.87%) was observed from D_1, while the minimum weight loss (4.64, 6.20, 9.58, 13.24 and 14.99%) was recorded from D_4. At 20, 40, 60, 80 and 100 DAS, the maximum percentage of rotten tubers (2.69, 3.69, 6.46, 7.69 and 9.49%) was observed from D_1, while the minimum percentage of rotten tubers (1.72, 2.54, 4.18, 5.10 and 7.18%) was recorded from D_4. The maximum days to start of sprouting (48.83) was observed from D_4, while the minimum days (44.00) was

recorded from D_1. The longest apical sprout length (1.84 cm) was observed from D_4, while the shortest apical sprout length (1.47 cm) was recorded from D_1. The maximum days to start of rottening (18.33) was observed from D_4, while the minimum days (15.17) was recorded from D_1. The maximum days to start of shriveling (87.08) was observed from D_4, while the minimum days (68.58) was recorded from D_1. The maximum days to 80% shriveling (150.17) was observed from D_4, while the minimum days (112.42 days) was recorded from D_1.

At harvest and 100 DAS, the highest specific gravity (1.12 and 1.14) was observed from D_1 and D_2, while the lowest specific gravity (1.08 and 1.11) was recorded from D_4, respectively for same data recording. At harvest and 100 DAS, the highest reducing sugar (0.29% and 0.59%) was observed from D_4, while the lowest reducing sugar (0.25% and 0.45%) from D_1. At harvest, the highest non reducing sugar (0.30%) was observed from D_4, while the lowest non reducing sugar (0.21%) from D_1. At 100 DAS, the highest non reducing sugar (0.23%) was observed from D_1, while the lowest non reducing sugar (0.18%) from D_4. At harvest and 100 DAS, the highest total sugar (0.59% and 0.78%) was observed from D_4, while the lowest total sugar (0.46% and 0.67%) from D_1, respectively for same data recording days. At harvest and 100 DAS, the highest starch content (18.22% and 20.03%) was observed from D_1, while the lowest starch content (17.25% and 18.86%) from D_4, respectively for same data recording days.

Due to the interaction effect of different variety and time of harvest at before storage and 20, 40, 60, 80, 100 DAS, the highest dry matter in peel (23.30, 23.66, 26.71, 28.20, 28.80 and 28.60%) was observed from and the lowest dry matter in peel (12.25, 14.16, 15.05, 15.50, 15.63 and 19.38%) was recorded from V_1D_1. At before storage and 20, 40, 60, 80, 100 DAS, the highest dry matter in flesh (16.99, 17.75, 18.80, 19.93, 21.71 and 22.07%) was observed from V_1D_4 and the lowest (13.62, 12.16, 12.86, 13.73, 14.24 and 14.40%) was recorded from V_1D_1 at same data recorded days. At 20, 40, 60, 80 and 100 DAS, the maximum weight loss (6.07, 7.26, 12.63, 18.04 and 19.60%) was observed from V_4D_1 and the minimum weight loss (3.53, 5.52, 8.21, 10.79 and 11.72%) was recorded from V_1D_4 at same

DAS. At 20, 40, 60, 80 and 100 DAS, the maximum percentage of rotten tubers (3.13, 4.13, 7.21, 8.41 and 9.91%) was observed from V_4D_1 and the minimum percentage of rotten tubers (1.33, 1.81, 3.23, 4.25 and 6.13%) was recorded from V_1D_4 at same DAS. The maximum days to start of sprouting (51.67) was observed from V_1D_3 and V_1D_4, while the minimum days (39.33) was recorded from V_4D_1. The longest apical sprout length (2.01 cm) was observed from V_1D_3, while the shortest apical sprout length (1.31 cm) was recorded from V_4D_1. The maximum days to start of rottening (20.00) was observed from V_1D_3, while the minimum days (14.00) was recorded from V_4D_1. The maximum days to start of shriveling (95.67) was observed from V_1D_3, while the minimum days (61.33) was recorded from V_4D_1. The maximum days to 80% shriveling (162.33) was observed from V_1D_3, while the minimum days (106.67) from V_4D_1.

At harvest and 100 DAS, the highest specific gravity (1.13 and 1.16) was observed from V_3D_1, while the lowest specific gravity (1.06 and 1.09) from V_1D_4, respectively for same data recording days. At harvest and 100 DAS, the highest reducing sugar (0.32% and 0.62%) was observed from V_4D_4, while the lowest reducing sugar (0.23% and 0.43%) from V_3D_1, respectively for same data recording days. At harvest, the highest non reducing sugar (0.32%) was observed from V_3D_4, while the lowest non reducing sugar (0.19%) from V_1D_1. At 100 DAS, the highest non reducing sugar (0.24%) was observed from V_1D_1, while the lowest non reducing sugar (0.17%) from V_1D_3. At harvest and 100 DAS, the highest total sugar (0.61% and 0.82%) was observed from V_4D_4, while the lowest total sugar (0.44% and 0.63%) from V_3D_1, respectively for same data recording days. At harvest and 100 DAS, the highest starch content (19.50% and 21.12%) was observed from V_3D_1, while the lowest starch content (16.97% and 18.50%) from V_2D_4, respectively for same data recording days.

Among the potato varieties BARI TPS-1 showed the best performance on the basis of post harvest physiology but HPS-364/67 was the best as per nutritional composition viz. specific gravity, starch content and reducing sugar when harvested at the same time.

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APPENDICES

Appendix I. Monthly record of air temperature, relative humidity, rainfall, and sunshine (average) of the experimental site during the period from March to August 2012

Month	*Air temperature (^{0}C)		*Relative humidity (%)	*Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
March, 2012	31.4	19.6	54	11	8.2
April, 2012	34.2	23.4	61	112	8.1
May, 2012	34.7	25.9	70	185	7.8
June, 2102	35.4	22.5	80	577	4.2
July. 2012	36.0	24.6	83	563	3.1
August, 2012	36.0	23.6	81	319	4.0

* Monthly average,

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix II. Analysis of variance of the data on dry matter content in peel of potato as influenced by different variety and days to harvest

Source of variation	Degrees of freedom	Mean square					
		Dry matter content in peel (%) at					
		Before storage	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
Variety (A)	3	16.405**	3.491*	23.234**	22.059**	13.342**	10.711*
Time of harvest (B)	3	81.984**	51.217**	189.534**	129.509**	115.873**	55.589**
Interaction (A×B)	9	11.098**	5.811**	6.790*	10.668**	15.437**	7.859*
Error	32	3.586	1.083	5.088	3.322	3.233	3.131

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix III. Analysis of variance of the data on dry matter content in flesh of potato as influenced by different variety and days to harvest

Source of variation	Degrees of freedom	Mean square					
		Dry matter content in flesh (%) at					
		Before storage	20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
Variety (A)	3	1.156**	2.702*	3.103*	1.729**	1.254*	8.577**
Time of harvest (B)	3	11.941**	40.070**	29.759**	24.696**	45.213**	61.842**
Interaction (A×B)	9	0.690**	1.885*	3.937**	3.561**	4.178**	3.945**
Error	32	0.236	0.743	0.811	0.394	0.374	1.317

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix IV. Analysis of variance of the data on weight loss of potato as influenced by different variety and days to harvest

Source of variation	Degrees of freedom	Mean square				
		Weight loss (%) at				
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
Variety (A)	3	2.076**	1.246**	10.405**	25.214**	37.603**
Time of harvest (B)	3	1.688**	1.348**	6.185**	20.305**	19.931**
Interaction (A×B)	9	0.871**	0.337*	1.270**	2.241*	3.590
Error	32	0.090	0.134	0.478	1.000	1.031

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix V. Analysis of variance of the data on percentage of rotten tubers of potato as influenced by different variety and days to harvest

Source of variation	Degrees of freedom	Mean square				
		Percentage of rotten tubers at				
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS
Variety (A)	3	1.718**	2.420**	5.444**	6.570**	8.032**
Time of harvest (B)	3	2.013**	2.782**	10.664**	13.854**	11.305**
Interaction (A×B)	9	0.148**	0.225**	0.400*	0.721**	0.771**
Error	32	0.037	0.061	0.192	0.229	0.226

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VI. Analysis of variance of the data on days to start of sprouting, apical sprout length, days to start rottening, days to start of shriveling and days to 80% shriveling of potato as influenced by different variety and days to harvest

Source of variation	Degrees of freedom	Mean square				
		Percentage of rotten tubers at				
		Days to start of sprouting	Apical sprout length (cm)	Days to start rottening	Days to start of shriveling	Days to 80% shriveling
Variety (A)	3	62.250**	0.026**	3.409**	81.521**	201.188**
Time of harvest (B)	3	62.306**	0.322**	23.243**	791.521**	3165.688**
Interaction (A×B)	9	34.324**	0.040**	2.521**	88.206**	135.076*
Error	32	8.896	0.004	0.542	12.563	51.271

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance

Appendix VII. Analysis of variance of the data on Specific gravity, reducing, non reducing, total sugar and starch content of potato as influenced by different variety and days to harvest

Source of variation	Degrees of freedom	Mean square									
		Specific gravity		Reducing sugar		Non reducing sugar		Total sugar		Starch content	
		At harvest	100 DAS	At harvest	100 DAS	At harvest	100 DAS	At harvest	100 DAS	At harvest	100 DAS
Variety (A)	3	0.002**	0.001**	0.006**	0.006**	0.002**	0.000*	0.004**	0.008**	7.297**	5.783**
Time of harvest (B)	3	0.003**	0.001**	0.003**	0.060**	0.020**	0.004**	0.038**	0.036**	2.229**	3.236**
Interaction (A×B)	9	0.0001*	0.0001*	0.001**	0.001**	0.001**	0.001**	0.001*	0.001**	0.122**	0.211*
Error	32	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.000	0.001	0.100

**: Significant at 0.01 level of significance; *: Significant at 0.05 level of significance